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Edited by
Dr.YS Ramkrishna
Dr.G Subba Reddy
Dr.GR Maruthi Sankar
Dr.G Ravindra Chary

Compiled by
Dr.GR Maruthi Sankar
Dr.G Ravindra Chary
A Girija
RVVSGK Raju

Technical Assistance
P Chandra Sekhar
L Sreeramulu
S Devika
I Usha Rani

Manuscript Processing
G Varalakshmi
N Lakshmi Narasu
S Sangeetha

Administrative Support
A Prema Kumari
SR Meena

Other Assistance
N Manikya Rao
V Amarender
L Nagaraju

Published by
Dr. YS Ramakrishna
Director
Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad-500059
(O) 040-24532262 (R) 040-24532262
Fax: 040-24531802
E-mail: ramakrishna.ys@crida.ernet.in

Printed at :
Sree Ramana Process Pvt. Ltd.
Sarojinidevi Road, Secunderabad - 500 003. Andhra Pradesh, INDIA.
Ph : +91-40-27811750 Fax : +91-40-27811751 E-mail : sreeramanaprocess@yahoo.co.in

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Santoshnagar, Hyderabad - 500059

Preface

Rainfed agriculture in India extends over 97 million ha across diverse agro climates, ecological situations and socio economic settings. In order to address the location specific problems, All India Co-ordinated Research Project on Dry land Agriculture (AICRPDA) initiated research on rainfed agriculture with 22 network centers and 8 Operational Research Projects (ORPs) for the last three decades. This project is continuing the efforts to generate site specific technologies in the areas of rainwater management, soil and water conservation, cropping systems, drought tolerant varieties, integrated nutrient, pest and energy management strategies, alternate land use options and farming systems for stabilized productivity and income. In addition, the ORPs located in different environs, are involved in participatory development and evaluation of the rainfed technologies for wider adoption.

The Annual Report (2005-06) of AICRPDA is a well-compiled research document with information based on 474 on-station trials and 129 on-farm trials across rainfed rice, maize, oilseeds, cotton and nutritious cereals based production systems. This report contains salient findings of technologies generated on-station and assessment and refinement of technologies under on-farm conditions in various production systems. In addition, this document contains information on focused research under AP Cess funded schemes. I hope the information contained in this report is very much useful for all the research institutes, agricultural universities and other stakeholders including NGOs involved in transfer of rainfed technologies.

I am grateful to Dr. Mangala Rai, Director General, ICAR and Secretary, DARE, Dr. J.S. Samra, Deputy Director General (NRM), ICAR for their guidance, support and encouragement for enabling to implement this project successfully. I am also thankful to Dr. A.K. Gogoi, Assistant Director General (Agronomy) for his continued support.

I wish to place on record the excellent contributions and cooperation by the Chief scientists, scientists from the network centers and ORPs for technology generation and dissemination and also help rendered by the authorities of respective State Agricultural Universities/Technical Universities/ICAR Institutes/International Research Organizations, the personnel from State line departments, NGOs etc., and ultimately farmers.

I wish to compliment the efforts of Dr. K.P.R.Vittal, former Project Coordinator (Dryland Research) for his continued efforts in coordination, monitoring and evaluating the technical program during the reported period. I also appreciate Dr.G. Subba Reddy, present Project Coordinator (Dryland Research), for his excellent efforts in coordinating the program and bringing out this report so meticulously in short time. I wish to appreciate the efforts made by Dr. G.R. Maruthi Sankar, Principal Scientist (Agricultural Statistics) and Dr. G. Ravindra Chary, Senior Scientist (Agronomy) in compilation and synthesis of data generated from AICRPDA network centers.

I acknowledge Ms.A.Girija, Mr.R.V.V.S.G.K.Raju, Mr.L.Sreeramulu, Mr.P. Chandrasekhar for data compilation and analysis, Ms.G. Varalakshmi and Ms.N. Lakshmi Narasu for secretarial help, Ms.A. Prema Kumari and Mr.S.R. Meena for administrative help and Ms.S. Devika, Ms.I. Usha Rani and Ms. S. Sangeetha for word processing and Mr.K. Gopalakrishna Murthy and other assistance by Mr.N. Manikya Rao, Mr.Amarender and Mr.L. Nagaraju.

(Y.S. Ramakrishna)

Contents

Executive Summary

The All India Co-ordinated Research Project for Dryland Agriculture has a network of 25 centers representing arid, semi-arid, sub-humid, humid and per-humid climates with diverse biophysical and socio-economic settings of the rainfed agro-ecologies of the country. The project has mandate to generate location specific technologies through on-station research focusing on rain water management/soil and water conservation, integrated nutrient management, cropping systems, crop improvement, energy management, alternate land use systems and farming systems in rainfed rice, maize, oilseeds, cotton and nutrious cereals (finger millet, pearl millet and sorghum) based production systems. The resultant technologies are subsequently assessed on farmers' fields under 8 Operational Research Projects. Out reach programs like Frontline demonstrations (FLDs) on pulses and oilseeds, on-farm trials through other externally funded projects like AP Cess schemes etc are also being undertaken**.** A total of 474 experiments were conducted at the 24 centers with a percentage of 21.7, 12.9,10.5,13.5,20.9, 0.4, 5.3, 5.1, 1.5, 5.9, and 2.3 under under INM, soil and water conservation, energy management, cropping systems; crop improvement; integrated weed management; alternate land use systems; integrated farming system, on-farm trials, front line demonstrations and other experiments respectively across the production systems.

These include 99 experiments on rice based production system (Jagdalpur, Jorhat, Faizabad, Phulbani, Ranchi and Varanasi), 51 on maize production system (Arjia, Ballowal-Saunkhri, Rakh Dhiansar), 77 on oilseeds based production system (Indore, Rewa (soybean based) and Anantapur, Rajkot (groundnut based), 32 on cotton based production system (Akola, Kovilpatti, Parbhani) and 215 on nutritious cereals based production system (Bellary, Bijapur, Solapur (*Rabi* sorghum based), Jhansi, Parbhani (*Kharif* sorghum based); Agra, SK. Nagar, Hisar (Pearlmillet based); Bangalore (Fingermillet based),

The salient findings from the research during 2005-06 are summarized below:

Rice Based Production System

In the rainfed Rice based production system, improved varieties of different crops viz., V-41 of pigeonpea at Phulbani, Birsa Dhan 109 of upland rice, BAU-20 of groundnut, Kanke white of sesame, Bahar (local red) of pigeonpea at Ranchi; TC-25 of sesame, coded entry '020104' of linseed, Malviya Arhar-6 of pigeonpea, L-345 of small seeded lentil and L-436 of bold seeded lentil at Varanasi were found stable.

Groundnut + pigeonpea (4:2), safed musli at Phulbani; paired planting of 3 rows of rice in 2 pairs of pigeonpea (50 and 100 cm) at Varanasi; and rice- niger-cowpea/sesbania, pigeonpea + okra at Faizabad recorded 20-40% higher yield and monetory reforms during this year, over traditional mixed cropping systems.

Among the rainwater management practices, furrow sowing for pigeonpea at Faizabad, straw mulch for early sown rice, life saving irrigation for late sown rice at Varanasi, lined pond with soil cement plaster (6:1 ratio with 8 cm thickness) with tomato at Phulbani, hoeing by dutch hoe between rows together with leaf and straw mulching in upland rice at Ranchi were identified as drought mitigation strategies in rainfed rice based production systems.

Recommended N for maize + pigeonpea and 30 kg/ha of sulphur for chickpea at Faizabad, 20 kg N (FYM) + 25 kg N (urea) for pigeonpea + rice and 50% N (urea) + 50% N (FYM) for yam + maize, 15 kg N (FYM) + 20 kg N/ha (urea) for rice + black gram, 30 kg N +20 kg P + 20 kg K + 30 kg N/ha (FYM) for upland rice, 40 kg N + 20 kg P + 20 kg K + FYM @ 5 t/ha for rice and lime @ 20% of lime requirement + FYM @ 5 t/ha for green gram at Phulbani, 40 kg N/ha for rice + black gram and FYM @ 5 t/ha + 20 kg N + 15 kg P + 10 kg K/ha for rice at Ranchi, and 50% N (urea) + 50% N (FYM) for rice – lentil sequence and 15 kg N (green leaf) + 20 kg N/ha (urea) for rice + green gram at Varanasi; 50% N (urea) + 50% N (organic) for rice at Jorhat; and 60 kg N + 50 kg P + 30 kg K/ha + blue green algae in rice at Jagdalpur were found as the nutrient combinations for optimum productivity.

Conventional tillage together with two interculture for rice – lentil sequence at Faizabad, conventional tillage together with one interculture for upland rice and low tillage + interculture for horse gram at Phulbani, low tillage together with two hand weeding for rice and linseed, hoeing with dutch hoe for groundnut at Ranchi, conventional tillage together with two intercultures for rice at Varanasi, and summer ploughing + line seeding by Indira seed drill + seed rate of 100 kg/ha + herbicide + sunhemp as green manure for rice at Jagdalpur were found as the most promising lpractices during the year.

Oilseeds Based Production System

JSP-40 and JSP-29 of groundnut, AT-93 of sesame, RTM-10 of green gram and SR-2462 of sorghum at Rajkot showed tolerance to drought. Water harvesting and supplemental irrigation of 10 mm through sprinkler for groundnut at Anantapur, and 30 cm distance with 3 rows on broad bed of 90 cm and furrow of 45 cm were superior in groundnut at Rajkot. Use of 10 kg N + 20 kg P + 20 kg K/ha + FYM @ 4 t/ha for groundnut at Anantapur, and 100% recommended N as urea for pearl millet, 50% recommended dose of fertilizer + 0.5 t/ha (vermin-compost) for cowpea, groundnut, 100% recommended dose of fertilizer for black gram and FYM @ 6 t/ha for green

gram and sesame at Rajkot were found optimum for realizing stable yields. Intercultivation with tractor drawn implement twice at 25 and 40 DAS at 30 x 10 cm spacing recorded stable productivity in groundnut at Anantapur. Under alternate land use, tamarind was superior for maximum stem girth of 36.8 cm under drip and 26.5 cm without drip irrigation in July 2005. Similarly, the girth was maximum of 39 cm under drip and 28.1 cm without drip in January 2006 at Anantapur.

Soybean Based Production System

Improved varieties of ICP-8863 of pigeonpea, JS-9305 of soybean and JNS-27 of niger at Indore, and JG-315 of chickpea, RWl-4 of lentil and 2K-0106 of linseed, TJM-15 of greengram , IU-83-5 of blackgram and JG-130 of chickpea were found suitable in vertisols of Rewa. Pigeonpea (Asha) + soybean (JS-335) in 1:2 ratio was a superior cropping system at Rewa, sowing across the slope + vegetative barriers with rosha grass, ridge and furrows system with 45 cm and polythene mulching for soybean at Indore were found as most suitable practices to improve the productivity of different crops in soybean based production system. 100% recommended N through urea for soybean and maize under sole and soybean + maize, FYM of 6 t/ha + 20 kg N + 13 kg P/ha for soybean and safflower at Indore, and 100 % recommended N through compost for maximum chickpea equivalent yield under rice-wheat, blackgram-chickpea and wheat-chickpea rotation at Rewa resulted in higher yields of the system. Low tillage + straw @ 4t/ha + hand weeding for soybean (1270 kg/ha) at Indore; and low tillage + weedicide + 50% organic + 50% inorganic fertilizer for soybean were superior at Rewa. Sowing with CRIDA planter for soybean saved labour and covered more area over other traditional drills at Indore. Drumstick + soybean + pigeonpea (4:2) was found superior compared to other agroforestry options at Indore.

Cotton Based Production System

Improved varieties KWA-23 and JKCDH-501 desi hybrid of *arboreum* cotton, L-763 of *hirsutum* cotton, AHT-8 of sunflower were superior at Kovilpatti. Soybean (JS-335) – chickpea (PKV-KAB-2) with 2700 and 899 kg/ha and cotton + pigeonpea (C-11) at Akola, and sorghum (CSH-9) + pigeonpea (BSMR-853) in 3:3 row ratio at Parbhani were found stable in predominantly cotton growing regions. Soil mulch with application of 20 kg K/ha for cotton + soybean at Akola, coir pith @ 5t/ha for cotton + maize at Kovilpatti, and opening furrow after every 4 rows for sorghum + pigeonpea (4:2), opening of furrow after every 4 rows + 100% recommended fertilizer for soybean + pigeonpea at Parbhani and Aurangabad (of respective crops) were found promising drought management technologies in cotton based production system.

Among integrated nutrient management practices, 25 kg N + 25 kg P + 25 kg N/ha (FYM) for cotton + greengram (1:1) with 1241 and 393 kg/ha of yield from respective crops, 15 kg N (compost) + 25 kg N (inorganic) for sorghum + pigeonpea with 2460 and 863 kg/ha of respective crops under intercropping and sole crops of sorghum and pigeonpea at Akola; FYM @ 40 kg N/ha for cotton + blackgram with 367 and 123 kg/ha, 20 kg N (urea) + 20 kg N (FYM) + 20 kg P/ha for sorghum + cowpea with 2158 and 112 kg/ha and 15 kg N (compost) + 20 kg N (inorganic) for sole sorghum and sole cowpea at Kovilpatti; and 100% recommended fertilizer for cotton + blackgram with 1158 and 399 kg/ha at Parbhani were found superior.

Under organic farming, 100% recommended fertilizer was superior in sorghum + pigeonpea system with 2399 and 1450 kg/ha yields, soybean + pigeonpea with 1731 and 1555 kg/ha, cotton + blackgram with 1520 and 453 kg/ha and greengram – *rabi* sorghum with 369 and 1769 kg/ha at Parbhani.

Conventional tillage + interculture in cotton + soybean at Parbhani, low tillage + herbicide + 50% inorganic + 50% organic fertilizer for sorghum at Akola, and conventional tillage + interculture for pearl millet at Kovilpatti recorded highest grain yields for rainfed crops. Ber + greengram at Akola, crop + goat + poultry + sheep + dairy at Kovilpatti improved the livelihood of farmers as the most appropriate farming system.

Nutritious Cereals Based Production System

Sorghum based production system

GPM-6 of horsegram, S-1635 of mulberry, GPM-425 of spreading groundnut, DH-103 of bunch groundnut, FMLT-11 of foxtail millet, BMLT-10 of barnyard millet, LMLT-5 of little millet, Jayadhar of cotton and DCS-5-1-47 of cowpea at Bijapur, HG-1 of horse gram, CK-05-AHT-41 of castor, G-5 of cluster bean, coded entry '050109' of linseed, coded entry '405-436-483' of *rabi* sorghum and MB-3 of mothbean at Solapur performed better. Pearlmillet + pigeonpea (2:1) at Solapur, and chilli + onion (2:4) with maximum net returns of Rs.71232/ha at Bijapur were found minimizing the risk. Seed hardening with $CaCl_2$ (2%) for 8 hours for *rabi* sorghum and chickpea and sand mulch of 10 cm depth for sunflower at Bijapur; and mechanical bunds + vertical plastic mulch for pearl millet at Solapur were identified as drought management practices.

Conventional tillage + one hand weeding + 100 % N (inorganic) for sorghum at Bellary; low tillage + 50% organic + 50% inorganic for pearl millet and conventional tillage + 25 kg N (urea) + 25 kg N (organic) + 12.5 kg P/ha for sorghum at Solapur; and conventional tillage + 100% recommended fertilizer (inorganic) for sunflower were found as suitable tillage management practices for higher yields of rainfed crops. Under alternate land use, aonla + drumstick + sunflower + pigeonpea was superior at Solapur.

Pearlmillet Based Production System

Among varieties, Bio-902 of mustard, JHB-887 of castor, GHB-558 of pearl millet and G-cot-21 of cotton at Dantiwada; HHB-67-2 of pearl millet, HC-98-96 of cowpea, HG-563 of clusterbean, K-851 of greengram, RMD-40 of moth bean, RH-

819 of mustard, HB-393 of barley, H-208 of chickpea at Hisar; and OS-sel-117 of sesame, JNS-27 of niger and HGS-02-1 of cluster bean at Agra were found stable during this year.

Pigeonpea + cluster bean (1:1) at Agra, paired row sowing of greengram (30-60 cm) between 2 pairs under green gram + castor relay cropping at Dantiwada, and 60:120x 60 cm + 2 rows of greengram at Hisar recorded 20-40% higher income compared to respective sole crops.

Crop residue mulch of castor together with kaolin spray @ 5% as an anti-transparent in castor, pearl millet + sunhemp (4:2) under paired rows of 30-60 cm with green manure at 30 DAS with pearl millet under late sown condition and ridges & furrows for castor at Dantiwada; and 4 cm irrigation at 50% flowering + 4 cm at 50% siliqua formation stage for mustard at Agra were identified risk mutigation in pearlmillet based production system. Seed treatment with Azotobacter (MAC-68) for pearlmillet, Azotobacter + phosphobacteria + FYM @ 4 t/ha for mustard; 10 kg N + 20 kg P/ha + inoculation of seed with PSB for greengram, 20 kg N + 40 kg P/ha for chickpea and 100% recommended fertilizer + FYM @ 8 t/ha for pearl millet at Hisar; recommended N of 60 kg/ha (inorganic) for sole pearl millet, sole cluster bean, pearl millet + cluster bean at Agra; and 50% N (inorganic) + 50% N (FYM) for castor and 100% recommended N for cluster bean under *Simarouba glauca* at Dantiwada were found as superior INM practices for optimum yields of rainfed crops.

Conventional tillage + interculture together with 100% inorganic fertilizer for pearl millet at Agra, and low tillage + interculture together with 50% inorganic + 50% organic fertilizer for cluster bean at Dantiwada were best tillage management practices. Under energy management, tractor drawn ridger seeder was superior for pearl millet, while 2-row ridger seeder under normal moisture and receding moisture conditions for mustard, and bullock drawn desi plough for chickpea at Hisar helped in timely sowing of rainfed crops.

Dicanthium annulatum + pearl millet under ley farming, and karingdo in 3rd row of pearl millet at Dantiwada; and Vetiveria (khus) for maximum survival, Aonla + *Sylosanthes hamata*, aonla + pearlmillet and integrated bio-diverse model with pulses + oilseeds and green fodder on 1 ha at Agra were found as the risk minimizing, systems besides improving land productivity and income per unit area.

At Bangalore, PBC-613 of chilli, NAH-2049 of maize, PKB-4 of cowpea for early and APC-552-70 of cowpea for late *kharif*, KB-280 of soybean, BDU-4 of black gram for early and late *kharif*, 2KM-137 of green gram, Doddabirenellu of rice, CK-05-IHT-35 of castor for seed and oil yield and KBC-2 of cowpea for green biomass yield showed promising results. Pond water for maximum green forage yield of pearl millet and green chilli yield, minimum runoff of 83 mm under natural vegetation (control) and khus live barrier was found superior for horse gram. FYM to supply recommended N + 50% NPK for soybean, FYM @ 10 t/ha + 50% recommended NPK for groundnut under FYM series under groundnut-finger millet rotation and 50% N through (green leaf) furrow placement + 50% NPK for finger millet were found optimum for higher yields. Conventional tillage + interculture + 50% N (organic) + 50% N (inorganic) for finger millet was found superior.

Maize based production system

Improved varieties of RT-334 of sesame, Pratap early makka-3 of maize, HG-1 of horsegram, ST-1-2 of blackgram and PTM-1 of taramira at Arjia; PBW-527 of wheat at Rakh Dhiansar; and PMH-2 of maize at Ballowal Saunkhri were found to increase the yields by 20-40% compared to the respective locals. Maize (50 cm) + blackgram (1:1) at Ballowal Saunkhri; and maize – blckgram at Arjia are found optimum to utilize the resources efficiently for higher income. Supplemental irrigation for maize + blackgram and groundnut + sesame, and ridges and furrows for maize at Arjia, and sugarcane mulch for maize at Ballowal Saunkhri helped to get 15-20% additional grain yield compared to the control in respective crops.

15 kg N (compost) + 10 kg N (urea) for maize + blackgram at Arjia; 100% recommended fertilizer for maize + blackgram, FYM @ 10t/ha + 40 kg N/ha + recommended PK for maize – wheat at Rakh Dhiansar and 100% recommended fertilizer for maize + blackgram at Ballowal Saunkhri were superior compared to the recommended dose of nutrients. Low tillage + interculture + 100% inorganic fertilizer for maize – wheat at Rakh Dhiansar; conventional tillage + interculture + 100% inorganic fertilizer for maize at Ballowal Saunkhri and conventional tillage + 2 intercultures + 50% inorganic + 50% organic fertilizer for blackgram at Arjia were identified as best INM practices for stable yields of rainfed crops.

Acacia tortilis + bunding under silvi-pasture system for maximum dry grass yield and pumpkin under agri-horti system at Arjia; gobi sarson for maximum green fodder and l*eucaena* + fodder – wheat at Rakh Dhiansar; and 45 x 30 cm spacing and mulching @ 6t/ha for lemon grass fresh yield at Ballowal Saunkhri were superior.

Operational research projects

AICRPDA initiated on-farm research through eight Operational Research Projects (viz., Ranchi, Arjia, Ballowal Saunkhri, Anantapur, Indore, Solapur, Hisar and Bangalore) to assess, refine and upscale the rainfed technologies in different environments. In this context, a total of 129 experiments were conducted in seven production systems under various themes, viz., INM (28), soil and water conservation (14) energy management (14); cropping systems (40); crop improvement (18); plant protection/weed management (8); and alternate land use systems (7).

The salient findings are -

Application of 20 kg N + 20 kg P/ha (basal) for upland rice with higher net returns and BC ratio (1.56); 40 kg K/ha with a

maximum net returns (Rs. 2996/ha) and BC ratio (1.57) was found best at Ranchi. At Arjia 50% N (organic) + 50% N (inorganic) was superior with a mean yield of 313 kg/ha for maize under maize + blackgram system. This gave 30.4% yield increase over application of entire fertilizer through inorganic source. At Ballowal Saunkhri, application of 50% N (FYM) + 50% N (inorganic) gave a significantly higher maize yield of 3805 kg/ha. Similarly, 40 kg P/ha was superior with a maize yield of 2580 kg/ha at Ballowal Saunkhri. 50% NPK (FYM) + 50% NPK (inorganic) was superior with a grain yield of 2470 kg/ha compared to farmers' practice with 1530 kg/ha at Bangalore. In groundnut 'TMV - 2' and pigeonpea 'TTB - 7' at Bangalore, application of bio-fertilizer gave a superior yield of 695 kg/ha of groundnut and 790 kg/ha of pigeonpea compared to control.

At Hisar, 40 kg N/ha was superior for pearl millet with a maximum yield of 930 kg/ha and mustard with a maximum yield of 980 kg/ha. At Anantapur, soil test based fertilizer application gave a pod yield of 1050 kg/ha compared to farmers' practice. 100% recommended dose (50 kg N + 60 kg P/ha) + sulphur @ 20 kg/ha was superior for soybean at Indore with a maximum yield of 1132 kg/ha, net returns of Rs.6373/ha and BC ratio of 1.94. At Indore, a significantly higher soybean yield was attained with application of 100% recommended dose of 30 kg N + 60 kg P/ha. This gave net returns of Rs.8625/ha and BC ratio of 2.32 and yield increase of 41% over farmers' practice. A significantly higher soybean yield of 1143 kg/ha with a yield increase of 46.5% over farmers practice was attained with application of 100% recommended fertilizer (30 kg N + 60 kg P/ha) together with zinc sulphate @ 25 kg/ha. This gave maximum net returns of Rs.6423/ha with a BC ratio of 1.91. 100% RDF + foliar application of 0.05% of zinc sulphate + 0.02% of boron at 30 and 45 DAS gave significantly higher soybean yield and yield increase of 52.5% over farmers' practice with a maximum net returns of Rs.6157/ha with a BC ratio of 1.83. At Indore, application of 80 kg P/ha as basal was superior with a significantly higher grain yield of 1561 kg/ha and a yield increase of 68.6%. At Solapur, 50 kg N + 25 kg P/ha gave a superior sorghum yield and returns compared to control with gross returns of Rs.10445/ha. Similarly, application of 50 kg N + 25 kg P + 25 kg K/ha was superior with a pearl millet yield of 1421 kg/ha and a yield increase of 15%.

Vandana variety of rice and Birsa niger–1 of niger at Ranchi; Navjot of maize and TAG – 24 groundnut at Arjia; horse gram, AK–42, and JH – 3459 of maize, SG-99 of groundnut; and PBW-527 of wheat at Ballowal Saunkhri; L–5 variety of finger millet, Samruddhi of green chilli, IT – 38956 – 1 of cowpea, PHG – 9 of horse gram at Bangalore; HHB – 67 – 2 of pearl millet and RH – 9304 of mustard, BH – 393 of barley at Hisar; JS – 9305 of soybean at Indore; BSMR – 853 of pigeonpea, Shradha of pearl millet, SS–56 and MSFH-17 of sunflower and MPQ-13 of maize at Solapur were found stable, with increasing yield and profitability by 20-40% over the respective locals in rainfed environment.

Pigeonpea + rice (1:3), pigeonpea + groundnut, pigeonpea + maize, Pigeonpea + okra (1:2) at Ranchi, maize + blackgram (2:2) at Arjia, Maize + blackgram (1:1), Wheat + raya (10:1) at Ballowal Saunkhri; maize + cowpea (green fodder) 3:1 at Bangalore; chickpea + chinese cabbage fodder At Hisar; Early sowing of groundnut + pigeonpea at Anantapur; maize-berseem, sunflower + pigeonpea (2:1), castor + cluster bean (1:2), and greengram in *kharif* and sorghum in *rabi* at Solapur were found profitable compared to sole cropping systems in the farmers' fields.

Weeding by grubber Birsa ridger plough at Ranchi, use of rotavator at Arjia, use of seed –cum fertilizer drill for wheat at Ballowal Saunkhri, tractor drawn mechanical seed drill at Anantapur helped for timely seeding, better establishment and optimum plant stand in farmers' fields.

Combination of dust mulching and mulching with Ipomea leaves in linseed at Ranchi; supplemental irrigation at 55 DAS for maize + blackgram (2:2), one supplemental irrigation at 45 DAS for groundnut + sesame (6:2), deep tillage + 100% recommended fertilizer through FYM and inorganic fertilizer for maize at Arjia; chiseling + mulching for maize at Ballowal Saunkhri; application of 10 mm water from pond during dry spell of more than 10 days for higher pod yield of groundnut at Anantapur; application of 2 protective irrigations at 35 and 65 DAS for sorghum and chickpea at Solapur were found for mitigation of moistures stress in rainfed crops.

The improved bio-diverse farming system at Arjia, improved practices for wheat, barley, raya and taramira at Ballowal Saunkhri; sesame, blackgram, greengram and cluster bean, maize + blackgram and groundnut + sesame at Arjia; greengram, mothbean, cluster bean and sesame at Hisar, groundnut at Anantapur; and sorghum, sunflower and safflower at Solapur recorded 50 –70% additional seed yield and net returns compared to respective local practices in farmers' fields under rainfed environment.

Weeding with kasola at 20 and 30 DAS in pearl millet at Hisar; dhek based agro-forestry model at Ballowal Saunkhri; cluster bean with ber at Hisar; bio-diverse farming system model with maize, sorghum, blackgram, horsegram, groundnut, sesame, ber, jatropha and medicinal crops at Arjia helped to stabilize the income and reduce risk for the farming community during this year.

As a part of on-farm trials the potentials of improved practices at non-ORP centers in respect of cotton, compartment bunding at Kovilpatti, Rhizobium seed treatment for chickpea at Dantiwada, use of Bio-902 variety of mustard and application of sulphur in mustard at Agra showed great potential in increasing the income.

In order to demonstrate the potentials of rainfed technologies Front Line Demonstrations (FLD) were organized on green gram (20) at Phulbani; chickpea (5) at Agra; pigeonpea (5) and chickpea (6) at Solapur; blackgram (7) and greengram (16) at Kovilpatti; pigeonpea (6) and chickpea (6) at Faizabad; chickpea (4) and lentil (3) at Ballowal Saunkhri. The improved practice in green gram at Phulbani (44.8%); pigeonpea (29.9%) and chickpea (23.2%) at Solapur; black gram (21.4%) and green gram (22.9%) at Kovilpatti, pigeonpea (33.4%), chickpea (35%) at Faizabad; lentil (53%) at Ballowal Saunkhri, chickpea (7%) at Rewa; and pigeonpea (45%) at Varanasi in respect of pulses. These trials have registered the yield benefits ranging from 7 to 53% under rainfed environment. Similar significant benefit was noticed by the farmers by adopting critical inputs in respect of oilseed crops predominantly grown in rainfed environment.

Monitoring and Evaluation

As part of monitoring and evaluation of research and outreach programs under AICRPDA network, various workshops/meetings organized during the period. These include - Twentieth Biennial Workshop at CRIDA, Hyderabad during 17-22 October, 2005; Annual Workshop of AP Cess Fund Adhoc Schemes at JAU, Junagadh during 30-31 January 2006; Working Group Meeting of AICRPDA Network Scientists and also meeting of AICRPDA Scientists with V QRT (CRIDA-AICRPDA-AICRPAM) at CRIDA during 6-10 March 2006; Sensitization Workshop of Capacity Building of Operational Research Projects at CRIDA during 20 October 2005; and Two Day Technical Workshop on Capacity Building of Operational Research Projects (AP Cess Funded Project) at CRIDA were organized during 17-18 February 2006.

Project Coordinator and other Scientists from PC Unit visited the centers for monitoring and evaluation of the technical programme, administrative and budgetary aspects etc. The proceedings of each visit were brought out during the visit itself for improving/any necessary action by PC (AICRPDA) or by the SAU authorities. During 2005-06, Akola, Anantapur, Indore, Parbhani and Rewa and ORPs at Anantapur and Indore were visited. Project Coordination Unit of AICRPDA has been monitoring 17 ICAR - ad hoc funded schemes with a budget amount of Rs. 281.11 lakhs. These projects were monitored since their submission through evaluation by experts, facilitating presentation of these projects in the Project Screening Committee at ICAR, monitoring the technical progress (half-yearly & annually) by organizing Technical workshops (Two such workshops were held during 2005 and 2006), budget sanctions and final submission to ICAR.

Various capacity building programs for the scientists under network centers and for diverse stakeholders were organized.

Linkages and Collaborations

AICRPDA Network Centers worked in close collaboration with the respective State Agricultural Universities (research, teaching and extension), ICAR/National Institutes (DOR, DMR, NRC on Sorghum, CPCRI for breeding programs, evaluation trials etc.) State and Central Govt. Departments, Private agencies, NGOs and other Stakeholders in the areas of research, training, extension and education and also providing the technical support on rainfed farming and watershed development etc. with national agencies. The centers also established linkages with Medicinal Plant Board, local national institutions for training programs and Ministry of Rural Development, Ministry of Water Resources, GOI for ad hoc projects. AICRPDA centers established strong linkages with NGOs like Rural Development Trust (Anantapur) etc. in their respective domains. A project on Monitoring and evaluation of A. P. Micro-irrigation project of Govt. of A. P was undertaken by Project Coordinator (AICRPDA) and Scientists from CRIDA. AICRPDA Centers at Bangalore and Anantapur involved with DFID- CRIDA collaborative project on "Enabling rural poor for better livelihoods through improved natural resource management. Project Coordination Unit, Hyderabad or AICRPDA Centers are also involved in externally funded projects viz., AP Cess funded (details are given in the Chapter on Adhoc projects.), PPIC funded, CSIR funded projects etc.,

Publications

There were 182 publications of AICRPDA project team, which comprised of 52 research papers published in journals, 31 presented in conferences, 21 books / bulletions / reports and 78 popular articles.

Budget (2005-06)

The total budget allocated for 22 network centers of AICRPDA for the period 2005-06 is Rs. 751.3 lakhs to generate site-specific technologies under different rainfed environments. About Rs. 120 lakhs is allocated for eight Operational Research Project centers to assess, refine and upscaling of rainfed technologies to improve the livelihoods of rainfed farming communities.

XX Biennial Workshop at CRIDA, 17-22, October, 2005

Second Annual Workshop of AP Cess funded Projects under CRIDA, 30-31 January, 2006 at JAU, Junagadh

Sensitization Workshop of Capcity Building of ORPs, 20 October 2005 at CRIDA, Hyderabad

Two Day Technical Workshop of Capcity building of ORPs , 17-18 February, 2006 at CRIDA, Hyderabad

1. Introduction

Rainfed Agriculture continues to occupy a prominent place in the country as it still represents 67% of net sown area contributing 44% food grain production and supporting nearly 40% human and 60% of livestock population. The major challenges posed today are decline in holding size continued low productivity (less than 1 t/ha), decrease in productivity growth in major rainfed crops (coarse cereals, oilseeds and pulses), unabated land degradation, threatening climate change mismatch between draught power and supply and inadequate fodder availability. This is further aggravated with continued yield gaps between research stations, on farm trials and farmer's fields.

To address these challenges/issues, the All India Coordinated Research Project for Dryland Agriculture, which was launched in 1970 with the core objective of achieving ***"better crop with every rain drop"***, through generating location specific technologies matching the diverse biophysical and socio-economic settings. The prioritized research programs undertaken were in themes of rain water management, cropping systems, crop improvement, integrated nutrient management, energy management, alternate land use system and farming system in a network mode through a network of twenty five centers. The designated mandate is -

Mandate

- To optimize the use of natural resources, ie., rainfall, land and water, and to minimize soil and water loss and degradation of environment;
- To evolve simple technologies to substantially increase crop productivity and viability;
- To increase stability of crop production over years by providing improvements in natural resources management and crop management systems and alternate crop production technologies matching weather aberrations;
- To develop alternate and sustainable land use systems; and
- To evaluate and study transferability of improved dryland technology to farmers' fields.

The project has a unique feature in its multidisciplinary approach and on-farm participatory systems research along with outreach programs like frontline demonstrations, on-farm trials etc. Along with this, for assessment and refinement of the location specific technologies generated at research stations, 8 Operational Research Projects (which started in 1974) conduct on-farm participatory research. Following the new paradigm of agro- ecosystems based research initiated during National Agricultural Technology Project (NATP), these 25 centers are now undertaking research in five production systems, viz., rainfed rice (6 centers), nutritious cereals (9 centers), maize (3 centers), cotton (3 centers), oilseeds (4 centers) with the Project Coordination unit at CRIDA, Hyderabad. The location of the Centers, ORPs and Organogram of AICRPDA is shown in Figure 1 & 2.

In 2005-06, 474 experiments were conducted at research stations under different production systems and theme areas where in 103 were on integrated nutrient management, 61 on soil and water conservation/rain water management; 50 on energy management; 64 on cropping systems; 99 on crop improvement; 2 on integrated weed management; 25 on alternate land use system and 11 other experiments. For technology refinement, 24 on-farm trials and 28 frontline demonstrations were also conducted. Seven experiments were also conducted in farming system research. 129 on-farm participatory research trials were conducted in ORP villages. In addition to the core this program both on-station and on-farm was strengthened through additional funding from AP Cess Scheme in key theme areas (361.2 lacs). Several adhoc grants were also released from PPIC, CSIR and IWMI.

For effective monitoring, the scientists from the co-ordination unit visited Akola, Arjia, Anantapur, Kovilpatti, Indore, Parbhani and Rewa during the year and reviewedthe technical programs, administrative and budgetary issues, staff position and proceedings were brought out at each center, a copy of which was submitted to PC (AICRPDA), Director, CRIDA and the concerned authorities of respective SAUs for further necessary action. Planning and monitoring were also done during Twentieth Biennial Workshop at CRIDA, Hyderabad during 17-22 October, 2005 and Working Group Meeting of AICRPDA Network Scientists and also meeting of AICRPDA scientists with V QRT (CRIDA-AICRPDA-AICRPAM) at CRIDA during 9-10 March 2006.

Project Coordination Unit of AICRPDA has been monitoring the technical progress (half-yearly & annually) of 17 ICAR - ad hoc funded schemes (with a budget of Rs. 281.11 lakhs). Two workshops were held during 2005 and 2006 to monitor AP Cess funded projects. Two Workshops viz., Sensitization Workshop (20 October 2005) and Two Day Technical Workshop (17-18 February 2006) on Capacity Building of Operational Research Projects (AP Cess Funded Project) were organized at CRIDA.

Many capacity building activities for the scientists and farmers were undertaken during 2005-06 at the centers and ORPs in coordination with respective SAUs, state departments, national institutions etc.

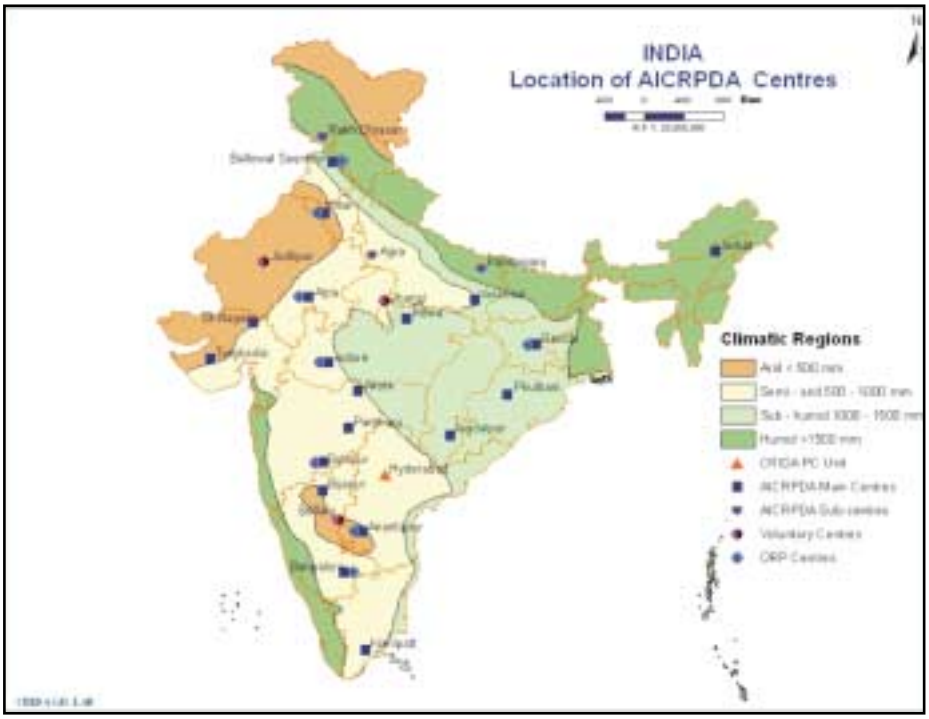


Fig. 1 Location of AICRPDA Network Centers

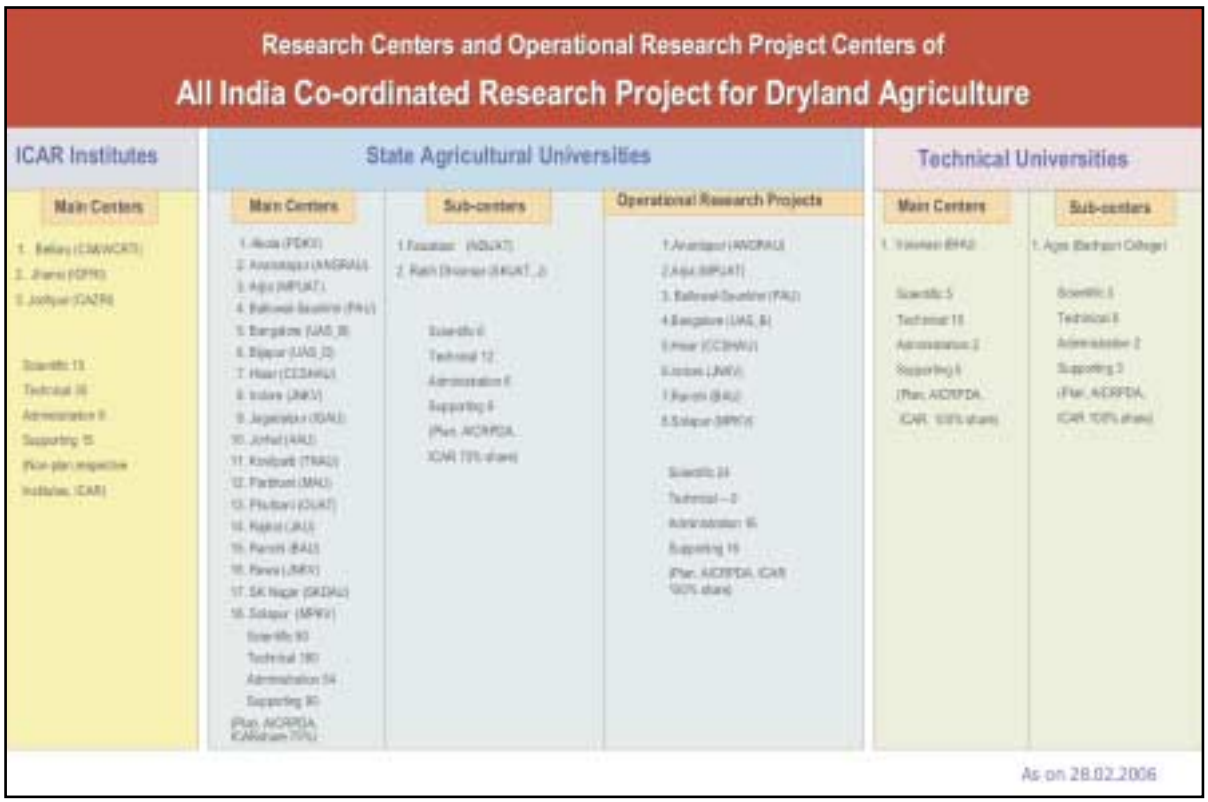


Fig. 2 Organogram of AICRPDA

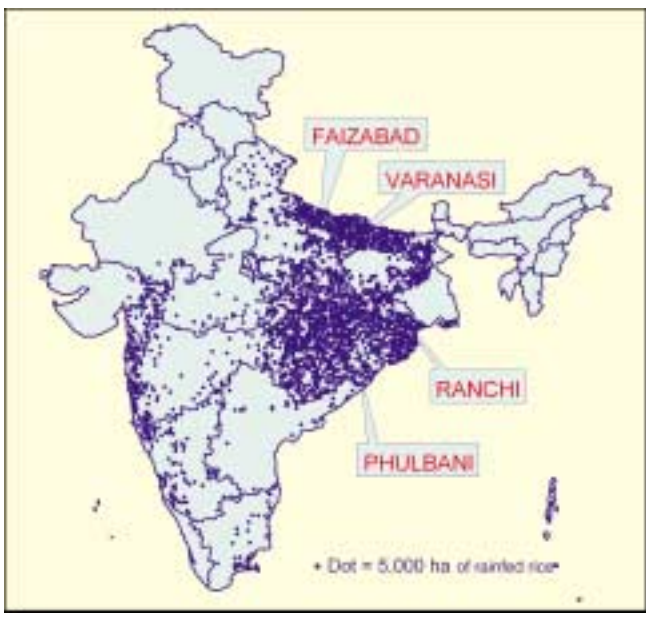
2. Site Characteristics of the Network Centers

The agroecological settings of the Network centers of AICRPDA are diverse in respect of climate, mean annual rainfall, length of growing period, physiography, available water capacity, drought occurrence, soil types, kinds and extent of soil degradation etc and recommendation domain. Rainfed crop production system-wise and center-wise details are presented below.

2.1. Rice Based Production System

In the rainfed rice production system six centers viz., Jagdalpur in Chattisgarh, Jorhat in Assam, Ranchi in Jharkhand, Phulbani in Orissa, Varanasi and Kumarganj (Faizabad) in Uttar Pradesh, are in the network of this project. The climate is sub-humid in this region with high rainfall. Sequence cropping is mostly practiced. Major soil orders are inceptisols and entisols in Uttar Pradesh, alfisols and entisols in Jharkhand, Chattisgarh and Orissa. In the rainfed zone of this domain, pulses and rainfed rice dominate at Varanasi whereas rainfed rice is the predominant crop in other regions.

Jagdalpur center is located in Bastar plateau, eastern plateau and eastern ghats, situated in between 17°46' to 20°34' North latitude and 80°15' east longitude with altitude ranging from 550-760 m above MSL (AESR 12.1) in hot moist and sub-humid agroecological subregion. This zone is surrounded by Koraput district of Orissa from east, Warangal and Khammam districts of Andhra Pradesh from South, Chandrapur district of Maharashtra from West. This zone is dominated with tribal population accounting about 67% of total population. The farming situations identified in this zone are 1. Badi (protected area near homested- *Entisol*, 2. Marhan- *Entisol*, situated down to the slope next by Badi having coarse textured, shallow and infertile soil. 3. Tikra-*Entisol/Inceptisol*, situated next to marhan down the slope and has relatively better and moisture retentive soil. 4. Mal-*Inceptisol* occurs below Tikra lands, generally bunded. 5. Gabhar-*Alfisol/Vertisol* occurs on valley part of topo sequence. Fields bunded and highly fertile. Soil erosion is measured by the land degradation in this region. At foothills of forests and hillocks soil acidity exists. pH ranges between 5.4 to 6.2, higher content and less electrical conductivity, low to medium available nitrogen, phosphorous and potassium, low inorganic matter content and low water available capacity (AWC). This is a sub-humid region with average annual rainfall of 1400 mm. Monsoon sets around 10th June and withdraws by mid October. Water deficit condition starts from 4th October. Bastar has 168 days of Length of Growing Period (LGP). Marhan, Tikra, Mal, Gabhar soils have severe, medium, slightly sloppy and flat topographic conditions. Entisols, marhan and Tikra situations are severely eroded and 70-75% of precipitation flows to the drainage lines in the form of run-off. Upland and hilly portion of area are lacking in vegetation and green grasses, while in low lying areas paddy crop is grown. The cropping systems in Marhan entisols are minor millets / niger-fallow / maize-toria. In Tikar entisols, upland paddy, minor millets, blackgram and pigeonpea are dominated. In Mal, double cropping system of rice – fallow or chick pea/linseed/safflower are grown. Rice - fallow/ chickpea/wheat & sunflower/vegetables are grown in Gabhar situation under irrigated conditions. The recommendation domain of the center is district of Jagdalpur, Bijapur, Dindori etc., in Bastar plateau.



* Jagdalpur and Jorhat to be added

Jorhat center is located in the Upland plain of Brahmaputra river system in Assam, (AESR 15.4). The climate is perhumid with hot summer and cool winter with a mean annual rainfall of 2500-3000 mm. Mean annual temperature is around 22-23°C raising to a maximum of 31°C in June and to a minimum of 10°C in winter (January). The rainfall starts by the end of March/ April and continues till October exceeding PET, while the precipitation declines seasonally during the months of November, December and January. LGP is above 300 days with medium AWC. Moderately deep to deep loamy alluvium derived soils are present in this region. The soil scape of the area is presented by hills, undulating uplands, gently sloping plains and charred lands. The soils of undulating uplands are inceptisols at some places (alfisols and ultisols are mostly under tea plantations). The soils of gently sloping plains are under both entisols and inceptisols and the soils of char areas are immature entisols. The soils of hills, uplands and gentle slopes are strong to moderately acidic (pH 4.4-5.6), whereas in the ravine areas the pH is neutral. Organic matter status is medium to high (0.7-2.5% OC) and CEC is medium to low. Rainfed agriculture is common. Rice and Jute are cultivated intensively in valleys.

Under rainfed conditions, common cropping is rice and jute in *kharif*, mustard, potato and other pulses in *rabi* with residual moisture. Rice is grown throughout the year in the region. Salli rice (winter rice) is dominant in Dibrugarh and Sivasagar, Boro rice (summer rice) is dominant in Sivasagar, while autumn rice is dominant in Dibrugarh. Wheat is common in *rabi*. Important horticultural crops in the region are orange, pineapple, banana, coconut and arecanut, while tea and citrus plant (upper terrace of the valley) are the important cash crops. Eri, muga and pat-based sericulture is a livelihood activity in these region.

The recommendation domain of the center is Golaghat, Jorhat, Sibsagar, Dibrugarh, Lakhimpur, Karbi Anglong (south and south eastern part), Dhemaji and Tinsukia.

Kumarganj (Faizabad) is located in Northern Plain, Rohilkhand, Avadh and South Bihar plains *(AESR 9.2*), having sub tropical-sub humid climate. Mean annual rainfall is 984 mm of which 85% of total rainfall is received during the monsoon period from June to September. Winter rains are unreliable and winter season is cold with occasional frost. Period from March to May is generally hot and dry, medium to high AWC, 90-120 days of LGP and drought once in ten years. The soils are deep loamy alluvium- derived. Soil reaction is almost neutral, electrical conductivity is sodic, organic carbon and phosphate are low, potash is medium, the soils are leveled and are on gentle slopes. The soils undergo chemical deterioration due to salinization (26-50% area), water erosion (11-25% area) with slight loss of topsoil, slight physical deterioration due to water logging (11-25% area). The traditional crops/cropping systems in *kharif* are rice, maize, pigeonpea, sorghum, pearlmillet, blackgram, greengram, sesame, groundnut, pigeonpea + groundnut/ blackgram, sorghum + greengram and in *rabi* are safflower, chickpea, pea, lentil, mustard, linseed, wheat and barley, chickpea + mustard, rice-chickpea/ lentil, pearlmillet - chickpea/mustard and sesame-chickpea/mustard.

The recommendation domain of the center is Faizabad, Sultanpur, Gonda, Basti, Barabanki, Jaunpur and Ambedkarnagar districts of Uttar Pradesh.

Phulbani center is located in Eastern Plateau (Chotanagpur) and Eastern Ghats, Garjat Hills, Dandakaraanya and Eastern Ghats *(AESR 12.1)* with tropical hot moist sub-humid climate, mean annual rainfall of 1597 mm (in 77 rainy days), monsoon (June-September), pre-monsoon (February-May) and *rabi* (October – January) periods receive 79, 10 and 11 percent of total rainfall, respectively. About 48 percent of the annual rainfall is received during July and August; the mean maximum temperature in the hottest month (May) is 38.4°C and the mean minimum temperature in the coldest month (December) is 7.7°C. The highest and the lowest temperatures recorded are 41°C and 1°C respectively, low to medium AWC drought occurs once in twenty years. LGP is 180-210 days, a regular toposequence of soils occur from upper hill to *Jhola* land through mid-hill, foothill, unbunded upland, bunded upland, medium and low land. The soils on uplands are well drained, light textured sandy loams and prone to crust formation and alluvial sandy clays occur in medium and low lands. Uplands constitute 45-81 percent of total cultivated area in different districts compared to state average of 46 percent. The upland soils are well drained, light textured sandy loams and prone to crust formation. Soil depth varies from 45 cm to more than 100 cm. Soils are acidic with low organic carbon, low available N, low available P and medium available K. Deficiency of calcium, sulphur and boron are noted. Phosphorus fixation is a problem due to low soil *p*H (5.0 -5.5). Alluvial sandy clays occur in medium and low lands. Iron toxicity occurs in medium and low land transplanted rice. The soils are deep loamy red, and lateritic. Soil reaction is acidic, electrical conductivity is normal, organic carbon is low, phosphate and potash availability is medium. Soil degradation is by water erosion with slight loss of topsoil (26-50% area). The traditional crops/cropping systems in *kharif* are; upland rice, maize, pigeonpea, fingerlmillet, blackgram, greengram, sesame, groundnut, castor, turmeric, ginger, mixed or intercropping systems of rice+horsegram/ pigeonpea, pigeonpea+rice /groundnut /greengram/ blackgram/ fingermillet /okra, sorghum +greengram on uplands, rice-linseed/rapeseed/mustard/greengram/blackgram, paira cropping of rice-lathyrus in medium lands and sequence cropping of rice-greengram/linseed/castor and relay cropping of rice-lathyrus and rice in jhola land and in *rabi* are niger, mustard and linseed.

The recommendation domain of the center is Phulbani, Boudh, Rayagada, Gajapati and Asoka districts of Orissa.

Ranchi center is located in Eastern Plateau (Chotanagpur) and Eastern Ghats, Chotanagpur Plateau and Garjat Hills *(AESR 12.3)*, sub-humid climate with total rainfall of 900 to 1500 mm with a high variation in the amount of total rainfall. About 90 percent of the total rainfall occurs during June to September. The rest 10 percent is received during winter. The monsoon is sharp peak, amounting to 200 to even 350 mm of rainfall in a week, with intensities as high as 250 mm per day. LGP is 150-180 days, medium in AWC drought occurs once in twenty years. Soils in general are moderately deep to loamy to clayey red and lateritic. The soils on the ridges are red, light textured and shallow, the upland soils are sandy loams, have moisture enough to grow only a single crop in *kharif*, soils in the medium lands are sandy clay loams and have adequate moisture for double cropping provided supplemental water is available for timely sowing of *rabi* crops. The lowland soils are invariably under rice and have also facilities of supplemental irrigation from tanks or wells. Crust formation in upland soils is a serious problem and available phosphorus is invariably very low irrespective of the location of the soils. The soils in several areas are acidic, moderately deep to loamy to clayey red and lateritic soils. Soil degradation is water erosion with moderate loss of topsoil (51-100 % area). The traditional crops/cropping systems in *kharif*

are; upland rice, maize, pigeonpea, fingermillet, blackgram, greengram, sesame, groundnut, mestha, jute, sorghum, soybean, horsegram, ginger, mixed or intercropping systems of pigeonpea + rice /groundnut /greengram / blackgram / fingermillet /okra, rice-niger /toria on uplands; sequence cropping of rice- linseed/ chickpea/safflower/lentil/raya/ niger and relay cropping of rice with lathyrus on medium lands; sequence cropping of rice- late sown wheat/tomato etc., in low lands.

The recommendation domain of the center is Gumla, Hazaribagh and entire plateau of Jharkhand state, parts of Rohtas, Gaya, Jamui in Monghyr district, Banka sub-division of Bhagalpur district in Bihar and Purulia and Bankura districts of West Bengal.

Varanasi center is located in Northern Plain, Rohilkhand, Avadh and South Bihar Plains situated in between 25°11' to 25°16' North latitude and 82°51'to 82°57 East longitude *(AESR 9.2)*, with hot dry sub-humid climate. The mean annual rainfall of the region is 1080 mm (909 mm dependable) and mean annual potential evapotranspiration is 1525 mm. The variability in commencement of South West monsoon is 37±9 and of withdrawal is 35 ±12 days. Moisture availability period extend from standard week 26 to 05 (moisture availability index 70.5) with growing season ranging between 26 to 30 weeks. LGP is 150-180 days, medium to high in AWC drought occurs once in six years. The region representing Varanasi mandal is located in physiographic belt of Northern plain, hot sub humid (dry) ecoregion of hot dry sub-humid Avadh and South Bihar plains, with deep loamy Alluvium derived soil. Landforms generally comprise Vindhyan hills (undulating topography) foothills and Vindhyan range (with depression) and plains (rolling topography), alluvial regions have uplands, midlands, lowlands, flood plains. Vindhyan region have upper plateau plains, escarpments, lower plateau plain, valley plain, reservoir and hillocks. The region represents broadly 3 major soil groups: alluvial soils (entisols and inceptisols), red soils (alfisols) and black soils (Vertisols). The soils are deep loamy alluvium-derived, soil reaction is neutral, electrical conductivity is suitable, organic carbon is low, phosphate is medium, potash is very low. Soil degradation is by water erosion with slight loss of topsoil (26-50% area), moderate physical deterioration due to water logging (11-25% area).

The traditional crops/cropping systems in *kharif* are; rice, maize, pigeonpea, pearlmillet, blackgram, greengram, sesame, maize + blackgram, pigeonpea + blackgram, pearlmillet + pigeonpea, and in *rabi* are safflower, chickpea, pea, lentil, rapeseed, mustard, wheat, barley, chickpea + mustard/barley/ linseed in *rabi* and the sequence cropping systems are rice-chicpea/lentil/mustard, maize-lentil, pearlmillet-chickpea, blackgram/greengram-mustard/barley etc.

The recommendation domain of the center is Varanasi, Chandauli, Sant *Rabi*das Nagar, Jaunpur, Ghazipur, Mirzapur, Sonbhadra districts and Vindhyachal commissionaires.

2.2. Oilseeds Based Production System

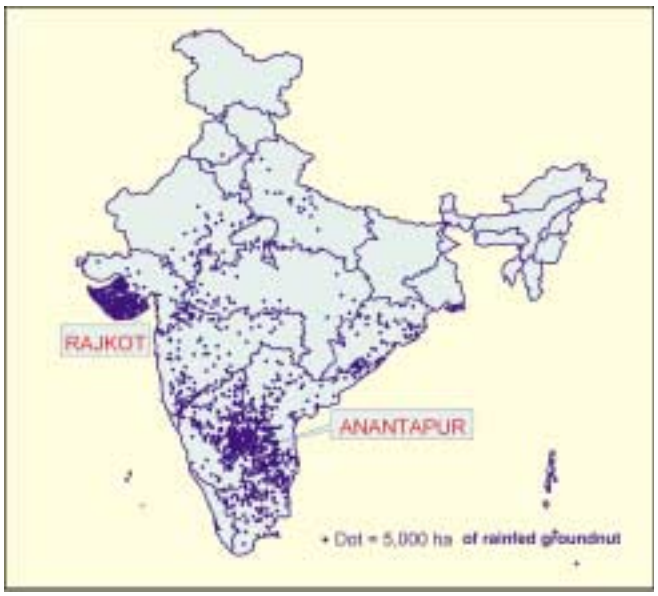
In the oilseeds based production system, four centers are located i.e, Anantapur and Rajkot located in predominantly rainfed groundnut production system of the country in arid climate in a contrasting soil and climatic situations, while Indore and Rewa are located in predominantly rainfed soybean production system in the state of Madhya Pradesh but in a contrasting physiographic and crop climate.

2.2.1. Groundnut based production system

Anantapur is in Rayalaseema- Karnataka plateau situated in between 20°32' to 20°35' North latitude and 77°7' to 77°10' East longitude with an altitude of 325 m above MSL (*AESR 3*), having arid climate. The decennial mean annual rainfall is 616 mm received in 36 rainy days. There is an increase in the rainfall during the period from 1990-2000. In the recent past, the sowing rains are being received during August first week instead of second fortnight of July. The decennial normal rainfall during *kharif* (June-September) is 394 mm, received in 21 rainy days among the months. The mean decennial rainfall in August turned out to be heavy rainfall month with 116.5 mm received in 6 rainy days. The analysis of the rainfall indicated that the crop is subjected to terminal season drought. AWC is low to medium. The soils of the region are red sandy loams with compact subsoil having 10-15 cm/m available water holding capacity and have serious crusting problem and high infiltration with near neutral in soil reaction, deficient in nitrogen and zinc and medium to high in potassium and phosphorus, electrical conductivity is suitable, organic carbon is low, phosphate is medium, potash is very low and Zinc is deficient. LGP is 90-120 days, drought once in ten years, soil degradation with water erosion is high (51-100% area) with moderate loss of topsoil. The traditional cropping systems in *kharif* are groundnut, sorghum, pearlmillet, setaria, castor, pigeonpea etc. and intercropping sytems are groundnut + pigeonpea etc.

The recommendation domain of the center is Anantapur, Kurnool and Chittoor districts.

Rajkot is in Western plain, South Kutch and North Kathiawar peninsular, situated in 21°10' North latitude and 70°40' east longitude with an altitude of 75-170 m above MSL *(AESR 2.4)*, having arid and semi-arid climates. This region receives rainfall during July to September. About 60 to 65 percent of total rainfall is being received only between the narrow window of July and August months. Annual rainfall over different parts of the zone varies from 350 to 650 mm distributed over 19 to 31 rainy days. LGP is 60-90 days, region predominated with *kharif* black soils. The major soil types of the North Saurashtra agroclimatic zone in order of priority are: medium black, coastal alluvial, shallow black, saline alkali, residual sandy and hilly. Soils are considered productive and highly retentive of moisture because of more clay content in general, the soils are sandy clay loam to clayey in texture, water holding capacity varies from 36 to 58 percent,



field capacity varies from 18 to 32 percent, wilting coefficient around 11 percent, bulk density varies from 1.2 to 1.8 g/cc, pore space ranges from 20 to 60 percent, infiltration rate is moderate to moderately low, soil reaction is neutral to alkaline, *p*H ranging from 7.4 to 8.5, electrical conductivity from 0.1 to 0.9 m mhos/cm (1:2.5), the electrical conductivity increases with soil depth and calcium carbonate content varies from 3.5 to 22.5 percent, rich in available potash, low to medium in available nitrogen as well as available phosphorus. Because of calcareous nature, the phosphorus fixing capacity is also high, available zinc and sulphur are also low. Drought occurs once in five years. Water erosion is (51-100% area) with moderate loss of topsoil, set-furrow (zonal) cultivation. The traditional cropping systems in *kharif* are groundnut, sorghum, cotton, greengram, pigeonpea, clusterbean, sesame, castor, maize etc. and intercropping systems are groundnut + castor/pigeonpea / sesame, pearlmillet +pigeonpea/ kidneybean, cotton + greengram, etc.

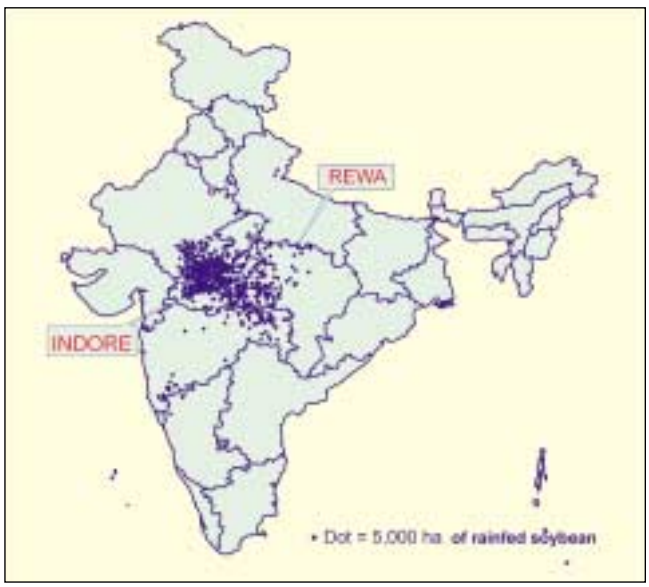
The recommendation domain of the center is Amreli, Bhavnagar, Junagadh, Jamnagar, Surendranagar and Rajkot.

2.2.2 Soybean based production system

Indore center is located in Central highlands (Malwa), Gujarat plain, Kathiawar peninsula semi-arid eco-region, situated in 22°51' North latitude and 75°51' East longitude with an altitude of 530 m above MSL (*AESR 5.1)*, having hot dry semi-arid climate. The annual rainfall for the region varies from 900 to 1000 mm, out of which over 85 % is received during the period from 24 to 39th standard meteorological weeks. Normally southwest monsoon sets at Indore in the second week of June but there are significant variations in the dates of onset of monsoon in individual years. The mean time of withdrawal of monsoon is third week of September. The duration of southwest monsoon at Indore is about 98 days, occurrence of intermittent dry spells is common. The soils are developed from basaltic parent material 'Basalt or Deccan trap' and are shallow and medium loamy to deep clayey black soils, AWC is medium, soil reaction is neutral, electrical conductivity is suitable, organic carbon is low, phosphate and potash are high, low in nitrogen, low to medium in phosphorus and high in potash, highly erodible and low in infiltration rate under saturated conditions in rainy season. Soil cracking is also a problem and soil mulching proves useful. Soil management problems arise due to poor soil physical conditions and inadequate drainage through excess runoff as well as waterlogging. LGP is 90-120 days. Water erosion (51-100% area) with moderate loss of topsoil and AWC is medium. The traditional cropping systems in *kharif* are soybean, maize, sorghum, greengram, blackgram, sunflower, pigeonpea etc, intercropping systems are soybean/sorghum + pigeonpea etc. the *rabi* crops are mustard, linseed, wheat, linseed, lentil, chickpea, safflower etc, and the sequence cropping systems are soybean-safflower/chickpea, maize/sorghum-chickpea/ safflower, greengram / blackgram - safflower/chickpea etc.

The recommendation domain of the center is Dhar, Indore, Ujjain, Dewas, Ratlam, Rajgarh, Mandsaur, Jhabua, Sehore and Shajapur districts.

Rewa center is in Central highlands (Malwa and Bundelkhand), Vindhyan Scarpland and Baghelkhand Plateau, is situated in the latitude 24 ° 30' north and longitude 81 ° 15' east at an elevation of 365.7 m MSL (*AESR 10.3)*, having hot dry sub-humid climate. The mean annual rainfall of 1100 mm received in 40 rainy days. About 54 percent of the annual rainfall is received during July and August, the mean maximum temperature in the hottest month (May) is 41.3°C and the mean minimum temperature in the coldest month (December) is 7.8°C, the highest and the lowest temperature recorded are 44°C and 0°C respectively. AWC is medium to high, LGP is 150-180 days. The soils are calcareous black and mixed red and clay

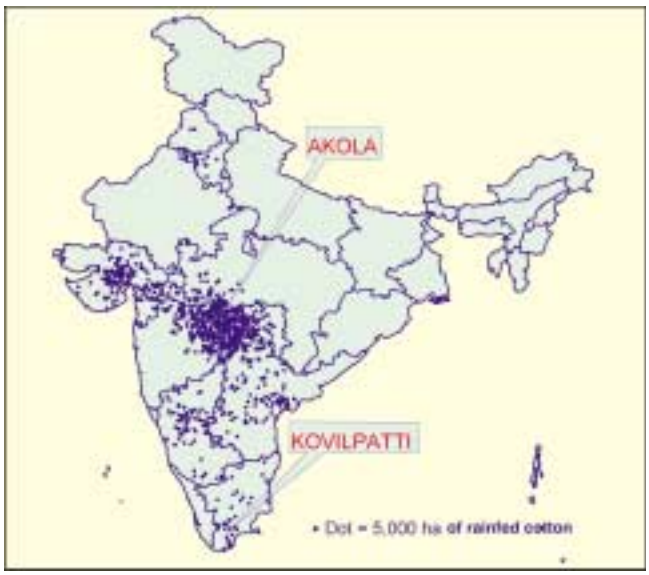


loams having enough storage capacity for double cropping, soils of upland and low land are well drained, light and heavy textured, the runoff collected is used for timely sowing of *rabi* crops, the soils are deep loamy to clayey mixed red and black soils. Soil reaction is neutral, electrical conductivity is suitable, organic carbon is low, phosphate is medium and potash is high, deficient in nitrogen and phosphorus whereas available K was found in adequate quantity, deficiency of Zn and S are noticed. Water erosion (26-50% area) is with moderate loss of topsoil. The traditional cropping systems in *kharif* are upland rice, lowland rice, soybean, sorghum, kodomillet, kutki, maize, pigeonpea, blackgram, greengram, sesame, groundnut, sunflower etc. Intercropping systems are soybean/ sorghum + pigeonpea. In *rabi* the crops are wheat, linseed, lentil, safflower, barley, lathyrus, mustard, chickpea etc.

The recommendation domain of the center is Satna, Sidhi, Shahdol, Umaria and Penna districts, North Eastern parts of Katni, Jabalpur and Dindori districts and Southern parts of Tikamgarh and Chhatarpur district of Madhya Pradesh.

2.3. Cotton Based Production System

Akola is in Eastern Maharashtra of Deccan Plateau, situated in the latitude 20 ° 32' to 20 ° 35' north and longitude 77 ° 7' to 77 ° 10' east at an elevation of 325 m MSL (*AESR 6.3*), having hot semi-arid climate. Mean annual rainfall is 813 mm. Soils are black, medium and deep clay loams to heavy clays, calcareous, with lime concretions (*kankars)* at varying depths, highly deficient in available phosphorous due to high phosphorous fixing capacity and have high moisture retention capacity but develop deep cracks from December onwards, electrical conductivity is suitable, organic carbon is low, phosphate and potash are high. Predominantly *kharif* cropping but double cropping is possible. LGP is 120-150 days. Water erosion is (51- 100% area) with moderate loss of topsoil, medium to high AWC and drought once in ten years. The traditional cropping systems in *kharif* are cotton, pigeonpea, pearlmillet, sorghum, greengram, blackgram and groundnut. Intercropping systems are cotton+pigeonpea/blackgram , sorghum + pigeonpea / greengram/ blackgram etc. and in *rabi* are safflower, chickpea, wheat, etc.



* Parbhani to be added

The recommendation domain is Akola, part of Amravati, Wardha, Parbani, Buldana, Yeotmal, east and west Khandesh districts of Maharashtra.

Kovilpatti is in Tamil Nadu uplands and leeward flanks of South Sahayadris and Deccan (Karnataka) plateau, situated in the latitude 9 ° 12' north and longitude 77 ° 53' east at an elevation of 90 m MSL (*AESR 8.1*), having semi-arid climate. The mean annual rainfall is 743 mm and the highest and lowest rainfall recorded so far were 1126 mm and 353 mm respectively. Mean monthly rainfall was highest of 189 mm (October) and the lowest was 16 mm (February). The rainfall during the months of April, September, October and November is fairly dependable and has less deviation. *Rabi*, summer and *Kharif* seasons receive a rainfall of 395, 156 and 150 mm respectively. The initial and conditional probabilities of receiving soaking rainfall of 20 mm and above per week indicated that, 63 percent probability occurs during the 42nd to 46th standard week. Hence, pre-monsoon sowing of sorghum, cotton and pulses could be taken up from 39th standard week onwards. The summer and south-west monsoon rains are insufficient to raise any crop because the evapotranspiration is high during this period due to high solar radiation and high wind speed. Thus, the length of growing period extends from October to January only. LGP is 90-120 days. The soils are moderately deep, clayey, retentive, slowly permeable, prone to erosion, highly deficient in phosphorus and have high phosphorus fixing capacity, depth varies from 150 to 200 cm, texture is clayey with the bulk density varying from 1.23 to 1.32 kg/m^3 in the surface soil, and while in the subsurface soil it ranges from 1.23 to 1.53 kg/m. Infiltration rate of the soil is low (0.5 – 0.9 cm/ hr) with a field capacity of 30-35 percent and having a permanent wilting point of 12-14 percent (with sunflower as indicator plant). pH tends towards alkalinity range both in surface and subsurface horizons, soils have highest CEC of 40 cmol (p+)/kg with low organic (0.55%) and higher base saturation percentage (99%) in surface and subsurface horizons with Exchangeable Sodium Percentage (ESP) within safer limit of 15, accumulation of salt is noted at lower depths (91 cm). During summer, these soils develop deep cracks of more than 1 cm wide and 50 cm deep due to the abundance of smectitic type of clay minerals noticed in the sub-soil. Electrical conductivity is suitable, organic carbon is medium, phosphate is medium, and potash is high, and is deficient in sulphur and calcium. Water erosion is (26-50% area) with slight loss of topsoil and medium AWC.

The traditional cropping systems are cotton, pearlmillet, maize, greengram, blackgram, cowpea, sunflower, sesame etc.,

and intercropping systems are cotton+ blackgram /clusterbean / coriander/sorghum+ cowpea/ blackgram /greengram, pearlmillet +clusterbean etc.

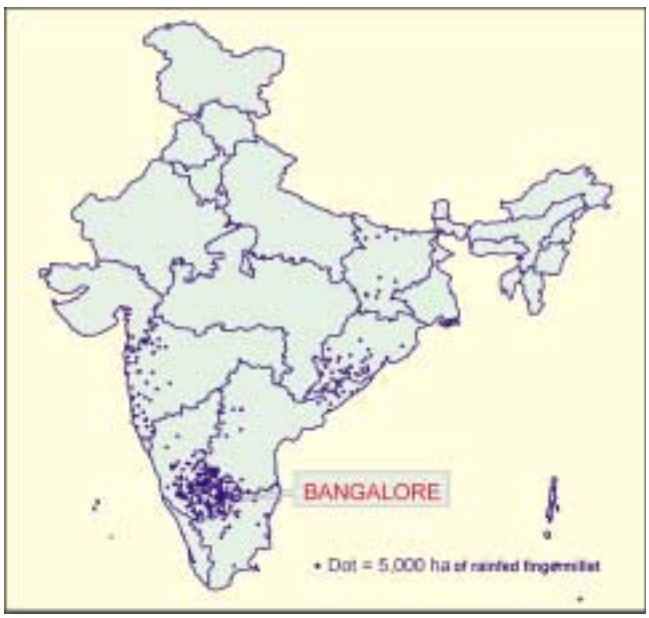
The recommendation domain of the center is Toothukudi, Tirunelveli, Madurai, Virudhanagar and other southern districts of Tamil Nadu.

Parbhani center is located in central and Western Maharastran Plateau *(AESR 6.2)* in hot moist semi arid ecological sub region with mean annual rainfall of 961 mm, shallow and medium loamy to clayey black soils (70-100 cm), pH (8.2) having bulk density of (1.29 g/cm^3) and medium to high AWC (32 to 33%) and LGP 120-150 days. The drought in this region occurs in 8 out of 18 years. The major *kharif* crops of this region are dominated with sorghum, cotton, pigeonpea, green gram, blackgram, pearlmillet and soybean. The major *rabi* crops grown in this area are sorghum, safflower, chickpea and sunflower. Mango, Sapota, Ber, Tamarind, Jamun, Custard apple and Amla. Cattle, buffaloes, goat, sheep and poultry are the major livestock.

The recommendation domain of this center is Nashik, Dhule, Aurangabad, Jalna, Nanded, Parbhani, Latur, Northern hilly part of Ahmadnagar and Jalgaon (western part). At Parbhani, the annual rainfall was 1318.9 mm against normal rainfall of 901.6 mm.

2.4. Nutritious Cereals Based Production System

In the Nutritious Cereals based production system, Arjia, Ballowal-Saunkhri and Rakh Dhiansar are located in predominantely rainfed maize based production system; Agra, Hisar and Sardar Krishi Nagar in rainfed pearlmillet based production system; Bellary, Bijapur, and Solapur in *rabi* sorghum based production system; and Jhansi and Parbhani in *kharif* sorghum based production system. These production based centers represent major staple food and fodder zones, drought hardy crops and diverse biophysical and socio-economic settings.



2.4.1 Fingermillet based production system

Bangalore is the only center representing rainfed finger millet based production system.

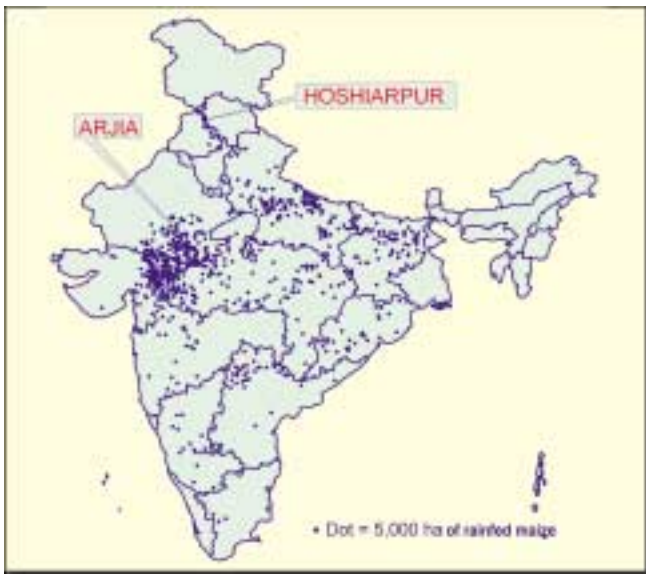
Bangalore is in Deccan (Karnataka) plateau of Central Eastern ghats situated in the latitude 12 º 46' to 12 º 47' north and longitude 77 º 11' east at an elevation of 810 m MSL (AESR 8.2). In Central dry zone: Annual rainfall is 607 mm, with two peaks of rainfall one in May and another in September- October. The normal annual rainfall is 768 mm in easten dry zone, Southern dry zone: The normal annual rainfall is 720 mm. The Central dry zone is dominated with red sandy to red loams with scattered patches of shallow to very deep black soils, low in organic carbon, medium in P_2O_5 and high in K_2O. The Eastern dry zone: has three major soil types (red loamy, red sandy and red lateritic), shallow in soil depth, low in organic carbon, low to medium P_2O_5 and high in potash. In Southern dry zone: these soils varied from red gravelly to red sandy loams, having shallow soil depth, well drained with very poor water holding capacity, neutral to acidic in reaction, low in organic carbon, medium in P_2O_5 and high in K_2O in dry lands. LGP is 120-150 days. Drought occurs once in five years. Water erosion (26-50% area) with moderate terrain deformation and loss of topsoil, AWC is low. The traditional crops/ cropping systems are finger millet, maize, little millet, foxtail millet, pigeonpea, greengram, blackgram, cowpea, fieldbean, horsegram, sunflower, castor, fingermillet + fieldbean, sorghum+pigeonpea in *kharif* and niger etc., in *rabi* and the sequence croppings are cowpea-fingermillet, greengram/blackgram -fingermillet, sorgum-horsegram etc.

The recommendation domain of the center is Bangalore (rural and urban), Kolar, Tumkur, Mandya, Hassan, Chamarajanagar, Chitradurga, Chikmagalur, Davanegere and Mysore.

2.4.2 Maize based production system

The research in the maize based production system is being carried out at Arjia, Ballowal-Saunkhri and Rakh Dhiansar. Among these, high rainfall is received at Ballowal-Saunkhri and Rakh Dhiansar.

Arjia is in North Gujarat Plain (inclusion of Aravalli range and East Rajasthan Uplands) hot dry semi-arid eco-sub region situated in the latitude 25 º 12' north and longitude 74 º 46' east *(AESR 4.2)*, mean annual rainfall is 656 mm (1960-2001) from June to end of September, out of which above 90 percent is received during July-August. Drought occurs almost twice in five years. LGP is 90-120 days. Soils are medium black loams, moderately retentive and calcareous and are alluvium-derived deep loamy gray brown. AWC is medium, soil reaction is neutral, electrical conductivity is suitable, organic carbon is low, phosphate is low, potash is low to medium. Water erosion (51-



100% area) with moderate loss of topsoil. The traditional crops/ cropping systems in *kharif* are maize, pearlmillet, castor, sorghum, pigeonpea, greengram, groundnut, blackgram, clusterbean, cowpea, horsegram, maize+blackgram, groundnut + sesame/ pigeonpea /sorghum /pearlmillet + cowpea / pigeonpea etc., in *kharif* and mustard, barley, chickpea, wheat, taramira etc., in *rabi* and the sequence croppings are sorghum/ maize/-mustard, blackgram /greengram /cowpea/sorghum – mustard, sorghum-safflower etc.

The recommendation domain of the Center is Bhilwara, Chittorgarh, Udaipur, Banswara, Dungarpur, Rajsamand and parts of Ajmer.

Ballowal-Saunkhri (Hoshiarpur) is in Western Plain Kandi areas of Punjab including Rohilkhand plains, hot dry/moist sub-humid transitional eco-sub region *(AESR 9.1)*. The annual rainfall is 1000 mm, 80 percent of which is received during late June to mid September. Mean monthly rainfall is the highest in July and lowest in April. Rainfall is relatively more erratic during sowing time of *kharif* crops and is erratic as well as low during sowing of *rabi* crops. Runoff varies from 20- 45 percent during monsoon period. Generally, summers are hot and winters are cool. The maximum temperature is generally recorded in the month of May-June (upto 41°C) and the minimum in the month of January (up to 30°C). LGP is 120-150 days. Drought occurs almost twice in five years. Soils of the region have three distinct physiographic units – hilly, gently to moderately sloppy agricultural land and stream affected marginal lands and the soils are deep, loamy to clayey alluvium-derived (including saline and sodic phases), AWC is medium, soils are neutral in reaction and low in organic matter content, deficient in nitrogen, low in available phosphorus and medium in available potassium and are generally light in texture with loamy sand and sandy loam, while northwestern part of the region has medium to heavy textured soils. Water erosion (11-25% area) with slight loss of topsoil, slight chemical deterioration (6-10% area) and slight waterlogging (6-10% area). The traditional crops/cropping systems in *kharif* are maize, pearlmillet, fodder sorghum, pearlmillet, clusterbean, cowpea, greengram, groundnut, blackgram, sesame, barley, triticale, lentil, linseed, wheat, taramira, chickpea, mustard etc., in *rabi* and the sequence croppings are maize-wheat/mustard, chickpea, pearlmillet-wheat/chickpea/barley, fallow-chickpea/wheat, cowpea-wheat etc.

The recommendation domain of the center is Patiala and Nawanshahr districts in Kandi area.

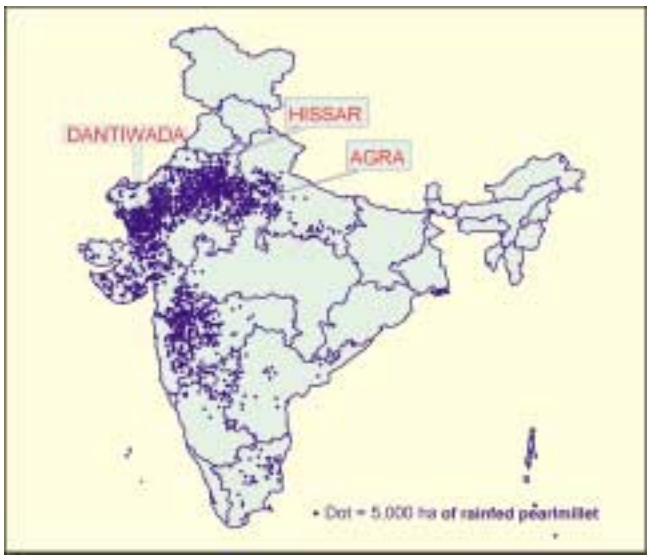
Rakh Dhiansar is in Kandi areas of Western Himalayas of South Kashmir and Kumaon, warm moist to dry sub-humid transitional eco-sub-region *(AESR 14.2)*. Mean annual rainfall is 1180 mm of which 60 percent is received during July-August. Winter rains account for 225 mm. LGP is 150-210 days. The soils are medium to deep loamy to clayey brown forest, podzolic and are medium deep sandy loam to loamy and low in nitrogen, phosphorus and low to medium in potassium, AWC is medium, soil reaction is neutral, electrical conductivity is suitable, organic carbon is low. Water erosion occurs (11-25% area) with slight loss of topsoil, slight chemical deterioration (6-10% area), slight waterlogging (6-10% area). The traditional crops/cropping systems in *kharif* are maize, pearlmillet, cowpea, greengram, blackgram, lentil, pea, mustard etc., in *rabi* and the sequence croppings are maize-wheat/ mustard/ barley/toria/ chickpea, blackgram-wheat/rapeseed etc.

The recommendation domain of the center is Jammu and Kathua districts.

2.4.3 Pearlmillet based production system

In pearlmillet based production system three centers viz., Agra, Hisar and SK Nagar are in the network of this project.

Agra is in Northern Plain (and Central Highlands) including Aravallis, North Punjab Plain, Ganga-Yamuna Doab and Rajasthan Upland (*AESR 4.1)* having semi-arid climate. Mean



annual rainfall is 665 mm, deep alluvial sandy loam soils, 90-120 days LGP, water erosion (26-50% area) with extreme terrain deformation, medium AWC. The traditional crops/cropping systems are pearlmillet, pigeonpea, clusterbean, cowpea, greengram, blackgram, groundnut, sesame, pearlmillet + pigeonpea/greengram etc. in *kharif* and mustard, chickpea, barley, oats etc. in *rabi* and the sequence croppings are greengram –mustard etc. The recommendation domain is Agra, Aligarh, Hathras, Etah, Mainpuri, Firozabad and Mathura districts in Uttar Pradesh.

Hisar is in Western Plain, Kachchh and part of Kathiawar peninsula, Rajasthan Bagar, north Gujarat Plain and southwestern Punjab plain (*AESR 2.3)*, having a sub-tropical, continental secondary, monsoonal type of climate with prolonged hot period from March to October and fairly cool winters. However, extreme temperature fluctuations may occur within a very short-time interval. Total annual rainfall is 320 mm (average of 31 years) with 290 mm in *kharif* and 40-60 mm in *rabi*. The average annual rainy days are 11 (10 years average). Probability of drought is once in 5 years. The water availability period is for 7-8 weeks (standard meteorological week 27-34). Usually the cropping period is 11 (29 to 39 standard weeks) and 24 (42-13 standard weeks) weeks in *kharif* and *rabi*, respectively. LGP is 60-90 days. The soils of Hisar district are aridisols (sierozem), deep, loamy desert soils (inclusion of saline phase), soil reaction is neutral, electrical conductivity is suitable, organic carbon is low, phosphate and potash are medium. Loamy sand to sandy loam soils are also found with calcium carbonate (concretions) layers at depths ranging from within the seeding zone to about 125 cm in patches at various locations. AWC is 120-270 mm/m and are characterized by high infiltration rate and low water holding capacity. Salinity is the serious problem in patches, particularly in irrigated areas. Almost all soils are deficient in nitrogen and zinc, low to medium in phosphorus and high in potassium. Wind erosion is of high severity with moderate loss of topsoil, affecting 26-50% area. Chemical deterioration is also of high severity moderate effect in 26-50% area. The traditional crops/cropping systems in *kharif* are pearlmillet, clusterbean, cowpea, mothbean, greengram, blackgram, castor, sesame, and mustard, chickpea, taramira, barley etc., in *rabi* and the sequence croppings are pearlmillet-chickpea /raya /fallow, fallow-raya/chickpea, greengram/ cowpea/ mothbean-raya etc.

The recommendation domain of the center is dry tracts of Hisar, Sirsa, Fatehbad, Bhiwani, Jhajjar, Mahendergarh, Rewari, Gurgaon, Kandi area of Panchkula and Ambala.

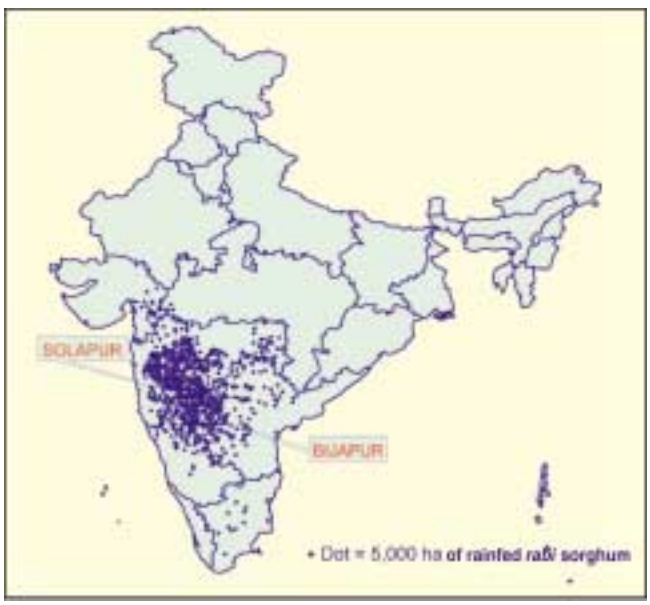
Sardar Krishi Nagar (Dantiwada) is in Western Plain, Kachchh and part of Kathiawar peninsula, Rajasthan Bagar, North Gujarat Plain and Southwestern Punjab plain situated in the latitude 24 ° 3' to 24°31' north and longitude 72 ° 13' to 72°45' east at an elevation of 152.5 m above MSL (*AESR 2.3)*. This center caters to both arid and semi –arid areas. Average annual rainfall is 550 mm and is received from last week of June to end of September. About 75 percent of the rainfall is received during June- August, ranifall is inadequate, uncertain and erratic. LGP is 60-90 days. Drought occurs twice in five years. The soils are deep, loamy desert soils (inclusion of saline phase), light textured loamy sand having high infiltration rate, poor water holding capacity and also poor in organic carbon and medium in available P and K content in soil, soil reaction is neutral, electrical conductivity is suitable, organic carbon is low, phosphate is medium, and potash is medium to high. Water erosion is of high severity with moderate loss of topsoil, affecting 11-25% area. 60-90 days LGP. Wind erosion (26-50%) with moderate loss of topsoil, moderate chemical deterioration due to salinization (11-25% area), low AWC. The traditional crops/ cropping systems in *kharif* are pearlmillet, castor, clusterbean, cowpea, greengram, sorghum, mothbean, karingdo, pigeonpea, pearlmillet + clusterbean + greengram + cowpea + sesame, greengram+pearlmillet, cowpea_castor, sorghum+karingdo etc.

The recommendation domain of the centre is Sabarkantha, Gandhi Nagar, Mehasana, parts of Patan, Ahmedabad and Banaskantha districts in Gujarat.

2.4.4 Sorghum based production systems

In *Rabi* sorghum based production system three centers viz., Solapur, Bijapur and Bellary are in the network of this project. While *kharif* sorghum based production system is addressed by Jhansi in Uttar Pradesh and Parbhani in Maharashtra.

Bellary is in Karnataka plateau including Rayalseema, situated in the latitude 14 ° 57' to 15°1' north and longitude 77 ° 17' to 77 ° 18' east (*AESR 3)* having arid climate with mean annual rainfall of 500 mm of which 50 percent is received during September-October. Rainfall from May to August is unreliable and that of during September- October is of a high intensity resulting in high runoff and the LGP is 90-120 days. The soils are deep loamy and clayey mixed red and black soils and are



medium and deep calcareous black clays. The most serious problem is extremely low infiltration rate, creating problems of soil and moisture conservation and this could be improved by reducing the Exchangeable Sodium Percentage to less than 5 percent by gypsum application and also by vertical mulching. Soils develop deep cracks about 6 weeks after the last rains; soils are deficient in nitrogen, phosphorus and zinc. Sub-soil salinity associated with high boron is another problem in the lower reaches of the slopes. Soil degradation is by water erosion with moderate loss of topsoil, affecting 51-100% area. The erosion severity is high, AWC is low to medium. Crops are grown under receding moisture conditions during *rabi* in deep black soils. Both *kharif* and *rabi* crops could be raised in medium deep black soils. The traditional cropping systems in *rabi* are sorghum, safflower, chickpea, beans, coriander, sunflower etc.,

The recommendation domain of the center is Bellary including parts of Chitradurga, Bellary, Raichur districts of Karnataka state and parts of Anantapur, Kurnool and Mahabubnagar districts of Andhra Pradesh.

Bijapur is in Karnataka Plateau, situated in the latitude 16 ^{o} 48' to 16^{o}50' north and longitude 75 ^{o} 50' to 75^{o}51' east at an elevation of 592 m above MSL (*AESR 3)*. This semi-arid region, receives a mean annual rainfall of 680 mm from May to October. Rainfall is bi-modal with peaks in July and September. LGP is 90-120 days. Drought is quite common and occurs once in five years. Soils are medium to deep black with patches of mixed red and black and low in phosphorus. Water erosion is of high severity with strong loss of topsoil and moderate loss of subsoil, affecting 26-50% area. The soils are deep loamy and clayey mixed red and black soils. Available water capacity is low to medium. Soil reaction is neutral. Electrical conductivity is normal. Organic carbon is low. Phosphate is low to medium. Potash is medium to high. The traditional cropping systems in *kharif* are greengram, blackgram, cowpea, pigeonpea, cotton, etc and in *rabi* are sorghum, safflower, sunflower, chickpea, etc. The intercropping systems in *kharif* are cotton+setaria, pearlmillet+pigeonpea and in *rabi* are sorghum+ pigeonpea/ chickpea etc.

The recommendation domain of the center is Bijapur, Bagalkot, Gulbarga, eastern parts of Belgaum, Lingsur of Raichur of Karnataka and Southern parts of Maharashtra.

Jhansi center is located in Northern plain, hot semi-arid eco-region *(AESR 4.4)* with deep loamy and clay mixed red and black soils, medium to high AWC and LGP 120-150 days. The traditional crops are sorghum, maize, millets, wheat, barley, pigeonpea, chickpea, lentil blackgram, sesame, linseed and mustard.

The recommendation domain of the center is Jhansi, Hamirpur, Lalitpur and Banda.

Solapur is in Deccan Plateau of South Western Maharashtra and North Karnataka Plateau, situated in the latitude 17 ^{o} 51' north and longitude 75 ^{o} 32' to 75^{o}37' east at an elevation of 480-510 m above MSL (*AESR 6.1)*, having semi-arid climate. Solapur receives 723 mm rainfall annually, which is not well distributed and annual potential evapotranspiration is 1856 mm resulting in 61 percent deficit. This is a rain shadow region due to Western Ghats. LGP is 90-120 days. Drought occurs once in ten years. Topography of this zone is rolling type. The soils exhibit a toposequence of very shallow (< 7.5 cm depth) and shallow (7.5 to 22.5 cm depth) soils on ridge, medium deep (22.5 to 90 cm depth) and deep (> 90 cm) in the valley. Soils are moderate to highly erodable, low in organic carbon (0.35 to 0.50 percent) and total nitrogen (0.035 to 0.05 percent), low to medium in available phosphate (10 to 30 kg/ha P_2O5) and high in available potash (300 to 750 kg/ha K_2O). Black soils show swelling and shrinkage phenomena. Predominantly *rabi* crops are grown in deep black soils, *kharif* and *rabi* crops in medium black soils and only *kharif* crops in shallow soils. Water erosion (51-100% area), with moderate loss of topsoil, medium to high AWC. The traditional cropping systems in *kharif* are pearlmillet, setaria, greengram, blackgram, pigeonpea, sunflower, groundnut, horsegram, mothbean, castor etc. and in *rabi* are sorghum, safflower and chickpea. The intercropping systems in *kharif* are pearlmillet+pigeonpea, sunflower+maize, castor+clusterbean/ridgegourd and the sequence cropping systems are blackgram/greengram- cowpea-*rabi* sorghum/ safflower/sunflower, pearlmillet/sunflower-chickpea, sorghum (fodder)-chickpea/safflower (one year rotation), two year rotation: safflower/chickpea-*rabi* sorghum, *rabi* sorghum/ chickpea-safflower etc.

The recommendation domain of the center is Western parts of Beed, Osmanabad, Aurangabad, some parts of Jalgaon, Buldana, Solapur, Ahmednagar districts, eastern parts of Nasik, Pune, Satara, Dhule, Nandurbar and Sangli districts in Maharashtra.

2.5 Rainfall and its Distribution during 2005-06

2.5.1. Rice based production system

Under rice based production system, Faizabad, Ranchi and Varanasi received a below normal rainfall of 21, 10 and 34% respectively, while Phulbani received 18% excess compared to normal. The actual rainfall received were 825 mm at Faizabad (against normal of 1051 mm), 1033.7 mm at Ranchi (1148.9 mm), 688.8 mm at Varanasi (1049.4 mm) and 1628.7 mm at Phulbani (1379.5 mm). Faizabad had a below normal rainfall in all months except July (314.9 mm against normal of 279 mm). Ranchi had deficit rainfall in all months except August (378.6 mm against normal of 282.9 mm). Varanasi had a deficit rainfall in all months. Phulbani had an above normal rainfall of 500.3 mm in July, 572.4 mm in September and 251.2 mm in October against a normal of 340.2, 221.4 and 88.3 mm respectively.

At Faizabad, the onset of monsoon was on 22nd June. It withdrew on 27th September. The crops were sown during 1st week of July. There was a dry spell of 10 days from 25th August to 3rd September. Because of well-distributed rainfall, the crops did not suffer any stress at any stage.

At Jagdalpur, a rainfall of 1587.7 mm was received against normal of 1532 mm during 2005. The cropping season received 1326.7 mm. Due to normal and well-distributed rainfall, rice and other crops did not suffer any moisture stress at any stage.

At Phulbani, monsoon started 12 days later than normal date and ceased 19 days later than the normal date. Accordingly, sowing of rice and other crops was delayed. Sowing of rice and other crops was done in 1st week of July. The crops received 44% less rainfall in 27th SMW, 73% less in 28th SMW, 65% less in 29th SMW, 99% less in 32nd SMW, 26% less in 33rd SMW and 63% less in 34th SMW. Although rainfall was below normal during 27th to 34th SMW, except 30th and 31st SMW, the crops did not suffer from moistures stress adversely due to better distribution of rainfall, adequate stored soil moisture and high degree of cloud cover. Crops received 288, 556 and 251% more rainfall during 31st, 37th and 38th SMW. In *rabi*, the plant population of horse gram and toria was normal, but crop growth, pod formation and filling were affected due to absence of rainfall in November and December.

At Ranchi, monsoon started in 25th SMW. The first dry spell was recorded in 35th SMW, which coincided with flowering stage of rice, pod formation of black gram and grain filling stage of sesame, which ultimately affected the yield. The 2nd long dry spell was observed in 39th and 40th SMW, which coincided with grain filling stage of long duration rice crop. In *rabi*, October received 49.4 mm rainfall. During November and December, there was no rainfall and the *rabi* crops failed due to moisture stress. Plant population was good at initial stage. However, the yield was low due to soil moisture stress at vegetative stage.

At Varanasi, late onset of monsoon (25th June) resulted in delayed ploughing and seedbed preparation, which led to, delayed sowings in mid July. The rainfall was erratic and poorly distributed leading to dry spells during crop growth and reproductive phase of crops. Late dry spells in August and September severely affected the standing crops, particularly upland rice. However, standing pulses and oil seeds performed well. September rainfall was more than 56% deficit and caused inadequate soil moisture for taking up land preparation and sowing of winter crops. The winter crops had poor germination and failed due to moisture stress.

2.5.2. Maize based production system

Under maize production system, a lower rainfall of 419.4 mm was received against normal of 657.7 mm at Arjia, 554.1 mm against 860 mm at Rakh Dhiansar and 597 mm against 1011 mm at Ballowal Saunkhri. There was an above normal rainfall of 179.8 mm against 96.6 mm in September at Arjia, while July month had above normal rainfall of 347.5 mm against 328.8 mm at Rakhdhiansar. There was a deficit rainfall in all the months at Ballowal Saunkhri.

At Arjia, the monsoon started in June and withdrew on 25th September. The crops were sown during 1st week of July. A long dry spell of 30 days occurred during middle of *kharif* season which adversely affected crop growth, flowering, grain formation and harvested yield of different crops. As a result of this crucial drought, most of the crops failed in the season.

At Ballowal Saunkhri, the onset of monsoon was in 26th SMW and ceased in 38th SMW. A rainfall of 696.9 mm was received during May 2005 to April 2006 from 43 rainy days, which was 63% of the average normal rainfall. Out of this, 81.4% was received during June to September 2005. The rainfall received during monsoon period was 63.1% of normal rainfall. Maize and other crops were sown during 2nd week of July.

At Rakhdhiansar, the monsoon started in 26th SMW and has withdrawn in 39th SMW with 26 rainy days. A rainfall of 544.1 mm was received which was 285.9 mm less than the normal in *kharif* season. The sowings were done in 27th SMW. In *rabi*, a rainfall of 187 mm was received from 14 days. There was no rainfall from 40th SMW to 52nd SMW, which adversely affected the sowing of mustard due to moisture stress. The occurrence of rainfall in the 1st SMW facilitated the sowing of wheat crop. A long dry spell of 18 days from 19th August to 5th September has affected the yield of maize and other *kharif* crops.

2.5.3. Soybean based production system

At Indore, the monsoon commenced in 23rd SMW, which was normal i.e., 4th to 10th June. The monsoon terminated on 1st October with a rainfall of 740.8 mm from 32 rainy days. The soybean and other crops were sown during 1st week of July. The crops did not face any severe stress during crop growth period since there was a normal rainfall in July, August and September months.

At Rewa, the onset of monsoon took place on 23rd June and continued with heavy rainfall from 28th June to 9th July. Due to this, the land preparation and timely sowing were delayed. July received a rainfall of 465.6 mm, which created a flood situation and sowing was delayed. The monsoon has withdrawn on 20th September. There was a rainfall of 746 mm from 51 rainy days in *kharif* season. Pigeonpea, cowpea, soybean were sown on 2nd August; rice on 18th July; greengram and blackgram on 25th July in the *kharif* season. A dry spell of 8 days from 8th August to 15th August and 12 days from 24th August to 4th September occurred in the season. The crops recovered although dry spells occurred in the middle of the season.

2.5.4. Groundnut based production system

Under groundnut production system, a normal rainfall was received at Anantapur, while an excess rainfall was received at Rajkot. Anantapur received 619 mm against a normal of 625.5

mm, while Rajkot received 1136.2 mm against a normal of 590.4 mm. A rainfall of 69.4 mm against 63.5 mm in June, 138.2 mm against 99.3 mm in July, 136 mm against 122.9 mm in August, 118.4 mm against 112.4 mm in September and 131.6 mm against 112.6 mm in October was received at Anantapur. At Rajkot, a high rainfall of 322.7 mm against 97.2 mm in June and 374.7 mm against 73.9 mm in September were received. Similarly, a rainfall 277.5 mm against 221.2 mm in July and 194.6 mm against 165.6 mm in August were received at Rajkot.

At Anantapur, a rainfall of 619 mm was received from 43 rainy days against a normal of 625.5 mm. The monsoon started in 23rd SMW and continued up to 31st October (44th SMW). There were 2 dry spells of 31 days from 15th June to 15th July; 15 days from 13th August to 27th August in *kharif* season. Groundnut and other crops were sown in 2nd week of July. Although there was a stress in the mid season, groundnut and other crops recovered due to the rainfall received in September and October.

At Rajkot, a rainfall of 1143.4 mm was received in 39 rainy days, which was 89.7% higher than the normal rainfall. The regular monsoon commenced on 19th June (25th SMW) and had a good distribution. Sorghum was sown on 24th June, while groundnut, sesame greengram and senna were sown in the 1st week of July. Heavy rainfall was recorded during 26th, 31st, 37th and 38th SMW. The crop yields were adversely affected due to continuous and heavy rainfall during these 4 SMW. The monsoon withdrew on 4th October (40th SMW). The yield of long variation crops like cotton, castor and pigeonpea were good. The yield of groundnut, pearl millet and sorghum were normal, while the yield of sesame and pulses was poor.

2.5.5. Cotton based production system

At Akola, a total rainfall of 754.5 mm was received in 43 rainy days against normal of 805.6 mm in 45 rainy days. Pre-sowing and land preparation was done with a rainfall of 16 mm received on 28th June. Dry seeding of cotton was done on 2nd July with a receipt of 8.5 mm rainfall. *Kharif* crops were sown on 8th and 10th July. The crops had a good growth with occurrence of rainfall during 26th to 38th SMW. There were no rains during 7th to 31st August, except 19 mm on 12th August and 11 mm on 20th August. These 2 rainfall events sustained the crop growth in blackgram and greengram. The rains occurred during 6th to 9th September and on 22nd September were crucial for all *kharif* crops. There was a break in monsoon from 23rd September to 14th October. The short duration pulses were affected due to moisture stress in flowering and grain formation stages. A 65 mm rainfall received during 15th to 17th October was useful for sorghum, pigeonpea, cotton and all contingent crops. The rainfall was also useful for timely sowing of chickpea and mustard.

At Kovilpatti, a rainfall of 855.6 mm was received from 47 rainy days against normal of 722.7 mm, which is 18.4% more than normal. North-East monsoon recorded a rainfall of 468.8 mm against a normal of 385.6 mm with an increase of 21.6 percent. The South-West monsoon recorded 109.8 mm against normal of 148.4 mm which is 26% deficit. The summer season recorded 263 mm rainfall against normal of 148.3 mm, which is 77.3% higher. The rainfall received during winter is 14 mm against normal of 40.4 mm, which is 65.3% deficit. Except January, February, June and September, all months recorded excess rainfall. The cropping season (September 2005 to March 2006) received 613.9 mm rainfall from 36 rainy days. Sowing of crops was done in 48th and 41st SMW. The heavy rainfall received during October and November caused flower shedding in pulses. The early establishment of crops was good due to sufficient rainfall. As there was sufficient rainfall during crop season, the yield of pulses and millets was satisfactory in spite of dry spells during 51st and 52nd SMW in 2005 and 1st SMW in 2006. The low distribution of rainfall during January badly affected the standing crops during reproductive phase, especially in cotton. The monsoon has withdrawn during 4th SMW in 2006.

2.5.6. Sorghum based production system

At Bijapur, a normal rainfall of 591.9 mm was received from 40 rainy days as against a normal of 594.3 mm from 38 rainy days. Rainfall was normal or above normal in July, August and October, while it was below normal in June and September. An above normal rainfall was also received in April and May 2005. A high rainfall of 66.1 mm in 28th SMW, 49 mm in 29th SMW, 70.5 mm in 35th SMW and 56.2 mm in 36th SMW was received. Receipt of early rainfall in April and May helped for grape pruning and land preparation for *kharif* crops. July rainfall helped for short duration pulses and sowing of pearl millet. Low rainfall in August till 25th helped for harvest of early sown *kharif* pulses viz., greengram and blackgram. Low rainfall in September hampered the sowing of *rabi* crops, particularly *rabi* sorghum. An above normal rainfall in October improved the sowing condition. There was a dry spell of 8 days each in August, September and October. There was no rain from October 28th onwards i.e., 44th SMW to 52nd SMW in 2005.

At Jhansi, the onset of monsoon was one week late and commenced in 27th SMW with rainfall of 84.4 mm. A good amount of rainfall of 33.1 mm in 28th SMW and 57.9 mm in 29th SMW was received. A high rainfall of 72.6 mm was received in 33rd SMW. The monsoon has withdrawn in 37th SMW. Jhansi received a rainfall of 372.9 mm during 2nd July to 15th October in 27 rainy days, which was 52.4% less than the normal of 781.8 mm. The *kharif* crops like sorghum, cowpea, maize, pearl millet and pigeonpea were sown during 22nd to 27th July. The *rabi* crops could not be sown due to lack of moisture.

At Solapur, the onset of rainfall was delayed by 5 weeks and it started in 28th SMW. During 2005, a rainfall of 758.9 mm was received from 49 rainy days which was 5% more than a normal rainfall of 721.4 mm. The rainfall received from June onwards was 651.1 mm in 43 rainy days. The distribution of rainfall was erratic, uneven and untimely. This influenced sowing time of crops, crop growth and yields. A useful rainfall of 107.8 mm in

6 rainy days was received as pre-seasonal rain for undertaking land preparation. The sowing of *kharif* crops was delayed up to 17th July due to absence of rains during 23rd to 27th SMW. Due to lapse of normal sowing period, mid-season correction was undertaken with crops like pigeonpea, castor, sunflower, horsegram and pearl millet. The germination and early growth was satisfactory. However, due to inadequate and erratic rainfall from September onwards, the reproductive phase of *kharif* sunflower and horsegram suffered. A dry spell of 18 days was experienced between 24th September to 11th October. The monsoon withdrew on 26th October (43rd SMW). The yield of *kharif* crops was below normal. In *rabi*, the sowing of sorghum, safflower, sunflower and chickpea were undertaken at normal time. A dry spell of 18 days during 24th September to 11th October affected the germination and early growth of *rabi* crops. A rainfall of 107.6 mm was received in *rabi* (38th SMW in 2005 to 8th SMW in 2006) from 8 rainy days, which was 55% below normal.

2.5.7. Pearl millet based production system

Under pearl millet production system, a deficit rainfall was received at Agra and Dantiwada, while a normal rainfall was received at Hisar.

A total of 630 mm in 30 rainy days, which was 17.1% higher than normal, was received in *kharif* 2005 at Agra. A high rainfall of 468.4 mm was received in July against normal of 185.7 mm, while a lower rainfall of 114.6 mm against 262.1 mm and 45.8 mm against 89.8 mm were received in August and September respectively. The crops were sown with the onset of monsoon in July. Due to continuous rainfall in July, the sowings were taken up in the first week of August. The crops were badly affected due to 10 days dry spell during 6-15 August and 22 days dry spell during 21st August to 13th September 2005.

At Hisar, a rainfall of 419 mm was received against a normal of 320 mm in *kharif* 2005. June received 56.6 mm against normal of 47.4 mm, while July received 163.7 mm against 122.4 mm and September received 192.3 mm against 40.4 mm. August received only 6.4 mm against a normal of 125.6 mm. There were 18 rainy days from June to September out of which there was an effective rainfall of more than 15 mm only on 8 days. Sowing of *kharif* crops was done in 2nd fortnight of July. The productivity of crops was severely affected due to a long dry spell of 31 days from 8th August to 8th September. The monsoon has withdrawn on 24th September.

At Sardar Krishi Nagar (Dantiwada), the monsoon started in 23rd SMW and has withdrawn in 40th SMW. A rainfall of 591.8 mm against a normal of 806 mm was received at Dantiwada. A higher rainfall of 101.1 mm against a normal of 87.3 mm in June, 245.5 mm against 278.1 mm in July and 236 mm against 142 mm in September were received. August received a rainfall of only 9.2 mm against a normal of 275.4 mm. Pearl millet and other crops were sown in the 4th week of June. Castor was sown in the first week of August. Long season dry spell of 14 days was observed from 28th to 30th SMW during monsoon season. Late season dry spell of 14 days was also observed from 34th to 35th SMW.

2.5.8. Finger millet based production system

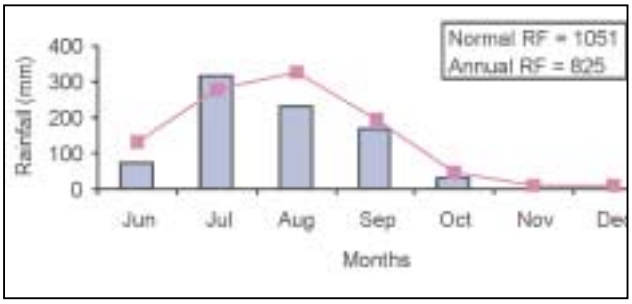
At Bangalore, a rainfall of 1358.2 mm, was received which was higher than normal rainfall of 928 mm. There were 62 rainy days during 2005.

April, May, June, and November received 105.4, 64.6, 40.2 and 41.1 mm rainfall, while July, August, September and October received 122.4, 249.2, 198.2 and 523.6 mm rainfall, respectively. A good rainfall distribution through out the year facilitated better establishment of finger millet, groundnut and other crops. The highest monthly rainfall of 523.6 mm was recorded during October against the mean of 178.6 mm. April, July, August and October months have recorded excess rainfall than normal. Except December month, all months received rains. Positive normal rainfall was recorded in April, and excess in October. Deficit rainfall recorded in February, March, May and August months. A maximum rainfall of 143.8 mm was received on 23rd October. The crops were sown in the last week of May. Forage crops were sown in the 4th week of May. Chilli was sown in the last week of June, while rice, maize, finger millet and groundnut were sown in the 4th week of July. Soybean and medicinal plants were sown in 4th week of August.

Jagadalpur

Jorhat

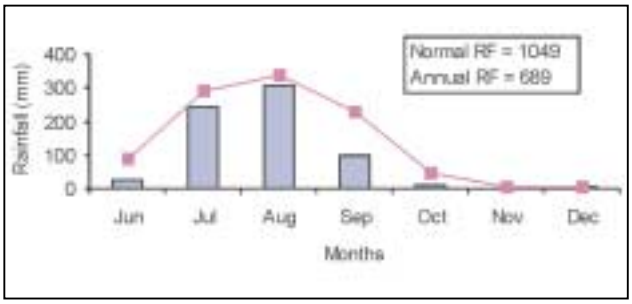
Faizabad



Phulbani

Ranchi

Varanasi



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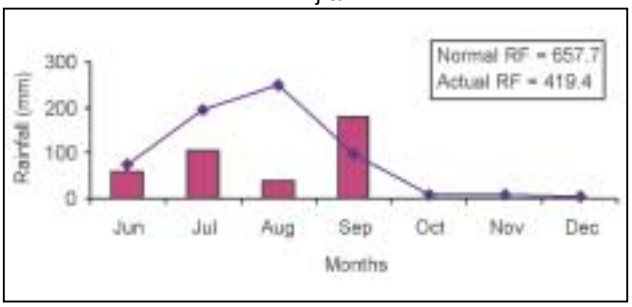
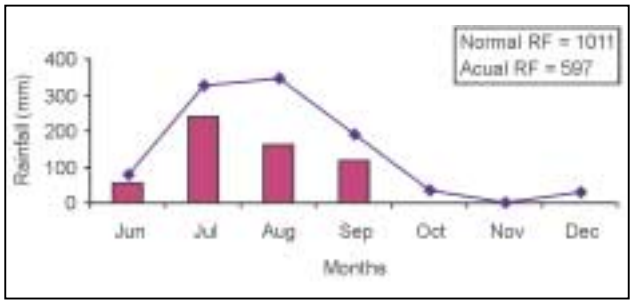


Ballowal Saunkhri



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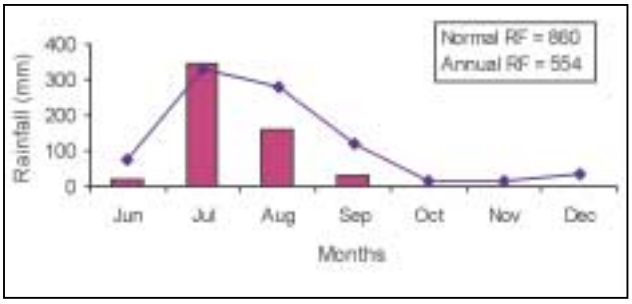


Fig. Rainfall distribution of different AICRPDA centers in rice and maize based production systems during 2005

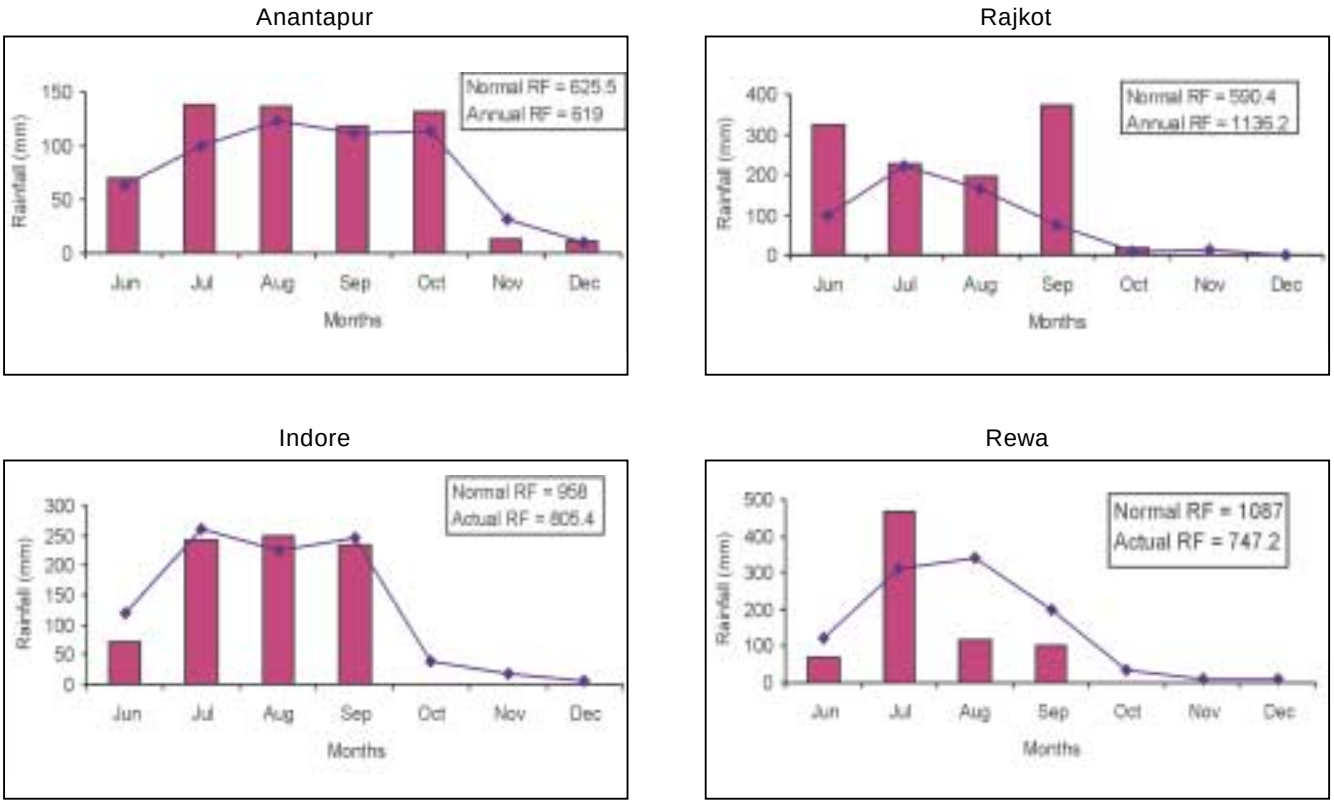


Fig. Rainfall distribution of different AICRPDA centers in oilseed (Groundnut and Soybean) based production systems during 2005

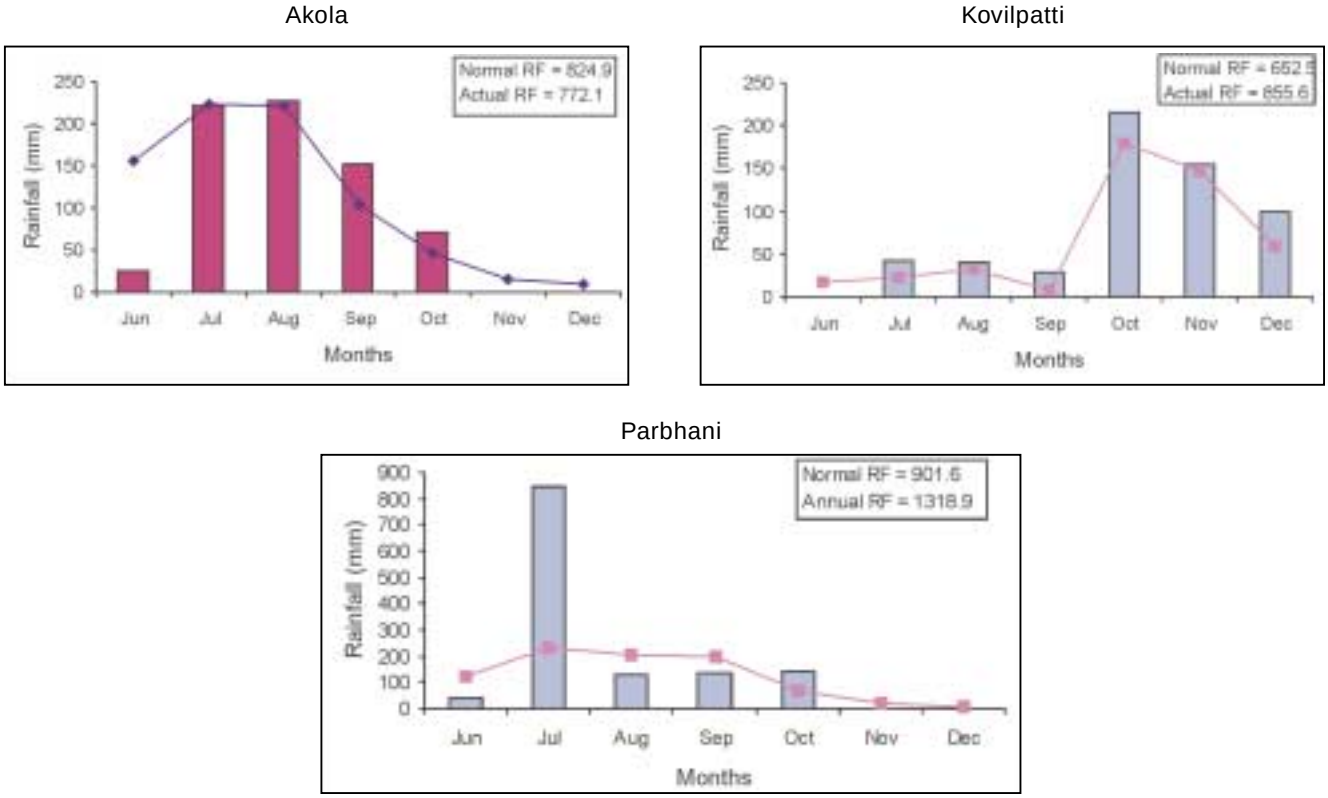
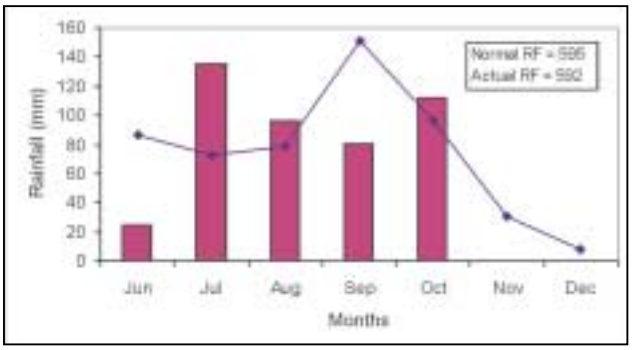


Fig. Rainfall distribution of different AICRPDA centers in cotton based production system during 2005

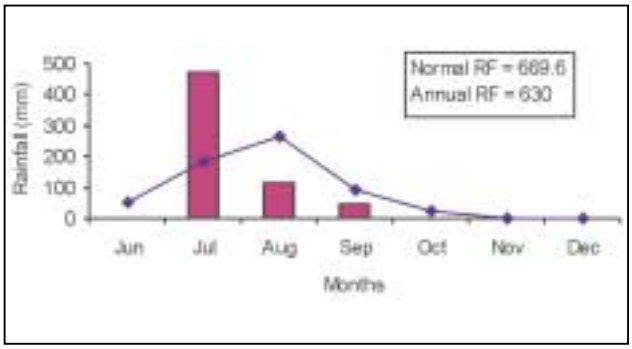
Bijapur



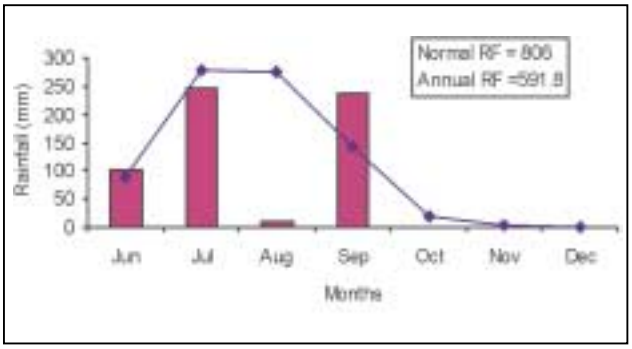
Solapur

Bellary

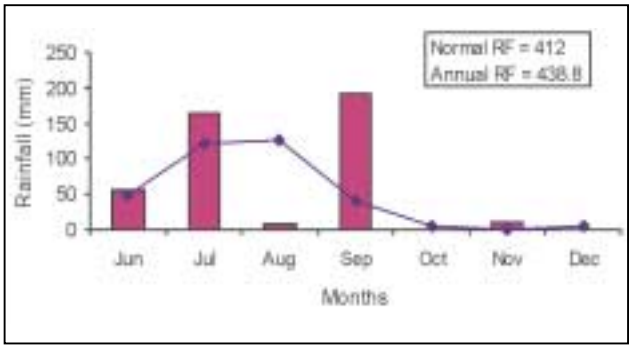
Agra



S.K. Nagar (Dantiwada)



Hisar



Bangalore

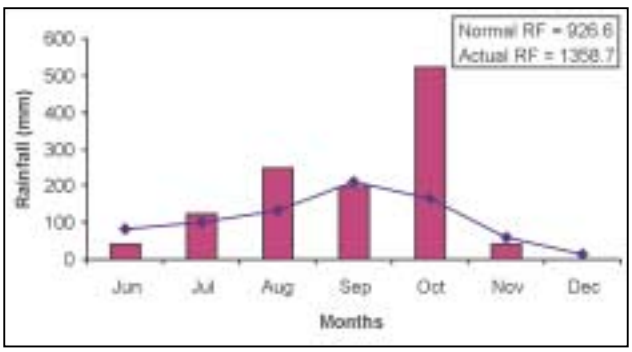


Fig. Rainfall distribution of different AICRPDA centers in Nutrious cereals Sorghum, Pearlmillet and Fingermillet) based production systems during 2005

3. Salient Achievements

3.1. Rice Based Production System

3.1.1. Crops and varieties

At Varanasi, the improved variety of pigeonpea (Malaviya Arhar-6) recorded the highest grain yield (3223 kg/ha), followed by Malaviya Arhar-18 (2780 kg/ha). In Lentil, the improved variety L-345 gave highest yield (1914 kg/ha), followed by L-334 (1790 kg/ha) during *rabi* season. In respect of bold varieties of linseed, the entry of 020104 gave the highest grain yield (1334 kg/ha), followed by 020101 (1222 kg/ha). Among the varieties of Greengram, Malaviya Janapriya (HUM-6) registered highest grain yield (1300 kg/ha), followed by Narendra mung-1 (1222 kg/ha). In Sesame, TC-289 yielded highest grain yield 700 kg/ha, followed by ES-3 (633 kg/ha).

At Phulbani, 16 Pigeonpea varieties were evaluated under rainfed upland situations. The variety UPAS-120 with 146 days duration was found better (784 kg/ha). While amongst long duration varieties, V-41, gave the grain yields of 1475 kg/ha. The long varieties were also found tolerant to pod borer. In Mustard, PARBATI, ANURADHA, QRT-7-5 recorded higher grain yield of 226, 195 and 275% respectively.

At Ranchi, the improved upland rice varieties of BAU-346-96, Birsa Vikasdan-110 and Birsa Vikasdan-109 yielded 1042, 1022 and 992 kg/ha and were found to drought tolerant. In groundnut, BAU-20, BAU-16 gave the pod yield of 1541 and 1480 kg/ha respectively. In respect of horsegram, the improved varieties of AK-22, Bastar white and Birsa kulthi gave additional grain yield of 112, 89 and 77 kg/ha compared to the local (954 kg/ha). The improved varieties of KANKE white (Sesame) and T-397 (Linseed) gave the highest grain yield **(Table 1 and 2).** At Faizabad, the improved varieties Narendra Arhar-1 and 2 in pigeon pea gave a grain yield of 2049 and 2176 kg/ha in rainfed environment.

3.1.2 Cropping systems

At Phulbani, the sole pigeonpea and turmeric crops recorded 2236 and 1009 kg/ha in upland situations. Among intercropping systems, turmeric + pigeonpea (10:2) recorded highest dry turmeric rhizome equivalent yield (1830 kg/ha). The rhizome yield in turmeric in intercropping system with pigeonpea was reduced to the extent of 18.2 % **(Table 3 and 4).** On the basis of rice equivalent yield, intercropping of groundnut with pigeonpea (4:2) increased the yield by 107, 40 and 41% respectively compared to sole rice (2187 kg/ha), sole pigeonpea (3231kg/ha) and sole groundnut (3203 kg/ha). Intercropping of groundnut with pigeonpea (4:2) gave 22% higher yield compared to pigeonpea with rice (5:2). Groundnut with pigeonpea system planted along the contour gave highest rice equivalent yield (4530 kg/ha) and lowest soil loss (8.613 t/ha) and lowest runoff of 345.3 mm followed by rice + pigeonpea system (3721 kg/ha). Cultivated fallow gave the highest soil loss (15.11 t/ha) and highest runoff 487.3 mm during the year of 2005-06.

Turmeric + Pigeonpea (10:2) at Phulbani

At Faizabad, pigeonpea + okra recorded highest maize grain equivalent yield (9915 kg/ha), followed by pigeonpea + kalmegh (9859 kg/ha) and pigeonpea + turmeric (9767 kg/ha). Among the sequence cropping systems, *rabi* crops like chickpea, lentil, mustard and barley can be successfully grown after the forage crops (maize + cowpea) under rainfed conditions. Among various sequences, forage-chickpea/lentil and blackgram-chickpea recorded highest barley grain equivalent yields 3993 kg/ha and 3703 kg/ha.

In Jorhat, *kharif* rice-niger-cowepa/sesbania and *kharif* rice-oak-cowpea/sesbania as green manuring crops recorded the highest rice grain equivalent yield of 4096 and 3958 kg/ha.

Among tuber crops, Yam (Orissa Elite), Cassava (Sri Jaya), Colocassia (Tellia), Sweet Potato (Sankar Variety), Yam bean (Rajendra Mishri Kanda-1), Elephant Footyam (Gajendra) and Arrow Root (Orissa Local) and an average recorded 22950, 24590, 12040, 23570, 16700, 33400 and 15170 kg/ha respectively. In tuber crops, Elephant footyam, Yambean and Sweet potato recorded the highest net returns of Rs. 63223, 60316 and 59256 per ha respectively. The improved varieties of

Rice + pigeonpea (2:1) at Varanasi

Table. 1. Influence of improved varieties of different crops on productivity and sustainable yield index in rice based production system

Center	Crop	Treatment	Yield (kg/ha)	Mean over years	SYI
Phulbani	Pigeonpea (3)	Kandula (Local)	639	872	0.30
		V41	994	1475	0.55
		ICPL – 87119 (Asha)	843	1108	0.40
		ICPL – 87051	769	1115	0.40
Ranchi	Upland rice (6) (MLT)	RR 347-1	848	1607	0.48
		Birsa Dhan – 109	1819	1673	0.50
		Birsa Dhan – 110	1784	1571	0.47
		Birsa Dhan – 108	1520	1487	0.44
	Rice (8) (IVT)	BAU 289-93	614	574	0.02
		BAU 346-96	1042	1236	0.32
		Birsa Dhan 110	1022	995	0.21
		Birsa Dhan – 109	992	1148	0.28
Ranchi	Groundnut (4)	BG 3(c)	1156	919	0.47
		BAU 20	1541	1442	0.73
		BAU 16	1480	1144	0.58
		BAU 18	1371	1361	0.69
	Sesame (4)	PKDS – 7	347	344	0.38
		Kanke White (c)	523	430	0.50
		PKDS – 5	467	363	0.41
		NT 14-91	459	368	0.42
	Upland rice (5) (MLT)	RR 286-14	1354	1189	0.26
		Birsa Vikas Dhan 110	2099	1365	0.33
		RR 347-167	2091	1282	0.30
		RR 433-1	2020	1494	0.38
		AK-22	1066	866	0.33
		Bastar white kulthi	1043	743	0.27
		Birsa kulthi	1021	981	0.39
	Pigeonpea (3)	ICP-7035 (CRIDA)	329	243	0.06
		Bahar (Local Red)	1633	1511	0.71
		MAL-4	1611	1135	0.52
		Bahar (Local black)	1400	1396	0.65
Varanasi	Sesame (3)	T-4	537	561	0.43
		TC-25	1019	829	0.69
		TC-289	889	816	0.68
		GT-1	852	624	0.49
	Linseed -1 (3)	020103	834	1391	0.28
		020104	1334	1319	0.25
		020101	1222	1327	0.25
		020106	1167	1685	0.41

(Figures in parentheses indicate no. of years of the experiments conducted)

Sesame cv TC-289 at Varanasi

Safed Musli collected from G.Udaygiri gave additional tuber yield (454 kg/ha) as against the local collection (1629 kg/ha).

3.1.3 Rainwater management

In Faizabad, ridge and furrow sowing and line sowing in pigeonpea gave additional grain yield of pigeonpea (387 and 204 kg/ha) compared to the broadcasting (1714 kg/ha).

In Varanasi, bunding during the *kharif* in rice enhanced the grain yield by 343 kg/ha compared to no bunding (1919 kg/ha). In another study, straw mulch in early sown rice, life saving irrigation and 2 percent urea spray for late sown pearlmillet

recorded additional grain yield of 190-200 kg/ha respectively compared to the control.

At Phulbani, intercropping of groundnut + pigeonpea (4:2) proved the best with respect of productivity, soil and moisture conservation. This system recorded rice equivalent yield (4133 kg/ha, soil loss of 4.01 t/ha and runoff loss of 207 mm as against 1715 kg/ha, 5.18 t/ha and 241 mm, respectively in case of sole rice. A cultivated fallow gave the highest soil loss of 8.8 t/ha and maximum runoff 328 mm. Thus the groundnut + pigeonpea (4:2) can be advocated in place of sole rice for maximizing the land productivity and minimizing soil and runoff loss. In respect of water harvesting, lined pond, unlined pond and control gave mean tomato fruit yield of 22830, 21330 and 19830 kg/ha respectively. The hydrological studies during November 2005 to March 2006 indicated that lined pond recorded the lowest water loss (86 lit/day) and 2.35 lit/day for wetted area in m^2. The water loss in unlined pond was the maximum (37000 lit/day and 1075 lit/ha for wetted are in m^2. The cost of lined pond was Rs. 9967/- while that of unlined pond was Rs. 2993/-. A cost of lining per square meter was Rs.88/-. The lined pond once filled up, is expected to dry up in 872 days, while the unlined pond actually dried up in 2.02 days **(Table 5 and 6).**

Table. 2. Influence of improved varieties of different crops on productivity at varanasi and ranchi centers in rice based production system

Center	Crop	Treatment	Yield (kg/ha)
Varanasi	Pigeonpea (2)	ICPL	1742
		Malaviya Arhar – 6	3223
		Malaviya Arhar – 8	2780
		Malaviya Arhar – 11	2761
	Lentil (IVT) (small seeded)	L – 345	1914
		L – 334	1790
		L – 336	1782
	Lentil (IVT) (bold seeded)	L-431	741
		L-436	1728
		L-432	1667
		L-434	1667
Ranchi	Rice (drought tolerant)	Birsa gora 102 (C)	871
		Richa –1	1436
		Vandana	1342
		Komal	1332

(Figures in Parentheses indicate no. of years of the experiments conducted)

Table. 3. Influence of cropping systems on productivity and sustainable yield index at Phulbani in rice based production system

Center	Cropping system	Treatment	Yield (kg/ha) Grain	GEY	Mean GEY
Phulbani	Rice (3)	Sole rice	2187	—	—
		Sole pigoenepa	3231	—	—
		Sole groundnut	1201	3203	3369
		Groundnut + pigeonpea (4:2)	803+875	4530	4134
		Rice + pigeonpea (5:2)	996+766	3721	3300
		Pigeonpea and groundnut in alternate strips	739+719	3612	3693
	Turmeric with pigeonpea (Turmeric eqt)*	Turmeric + pigeonpea (2:10)	427+1536	1830*	—
		Sole pigeonpea	1009	1009	—
		Sole turmeric	2236	2236	—
		Pigeonpea + turmeric (1:3)	1139+719	1527	—
		Pigeonpea + turmeric (2:6)	926+936	1586	—
Varanasi	Pigeonpea+ rice (2)	Rice + pigeonpea (2:2) at 75 cm	2013 (F) + 3051 (P)	—	—
		Paired planting of 3 rows of rice in 2 pairs of pigeonpea (50 + 100 cm)	2128 (F)+ 3022 (P)	—	—
		Paired planting of 4 rows of rice in 2 pairs of pigeonpea (30 + 120 cm)	1994 (F) + 2615 (P)	—	—

Center	Cropping system	Treatment	Yield (kg/ha) Grain	GEY	Mean GEY
Jorhat	Rice	*Kharif* rice-Pea-Cowpea/sesbania	3725	—	—
		Kharif rice-Niger-Cowpea/sesbania	4096	—	—
		Kharif rice-lathyrus- Cowpea/sesbania	3958	—	—
		Kharif rice-linseed-Cowpea/sesbania	3892	—	—
Faizabd	Maize (1)	Maize+turmeric	2778 + 9028	8194[x]	—
	(Maize eqt)[x]	Maize + aswagandha	2639 + 4167	6806	—
		Pigeonpea + okra	1562 + 6146	9915	—
		Pigeonpea + kalamegh	1562 + 2430	9859	—
		Pigeonpea + turmeric	—	9767	—

(Figures in Parentheses indicate no. of years of the experiments conducted) (F indicates fodder yields)

Cassava cv. Sree Jaya at Phulbani

Colocassia cv. Telia at Phulbani

Table. 4. Influence of crop diversification on productivity and profitability in tuber and medicinal corps at Phulbani

Center	Crop	Treatment	Yield (kg/ha)	Mean yield (kg/ha)	Gross Returns (Rs./ha)
Phulbani	Tuber crops (3)	*Colocassia* (Telia)	9810	1204	16879
		Elephant foot yam (Gajendra)	33400	3340	63223
		Yam (Orissa Elite)	28010	2295	43100
		Cassava (Sree jaya)	26390	2459	41139
		Sweet potato	15890	2357	59256
		Yam bean (Rajendra)	15330	1670	60316
		Arrow root (Orissa local)	12840	1517	36346
	Medicinal plants (2)	Safed musli (Local collection)	988	1103	—
		Safed musli G.Udayagiri (Original source – ONCC, Berhampur)	2083	2430	—
		Safed musli KVK, Bhanjanagar (Original source – Local collection)	1629	1589	—

(Figures in Parentheses indicate no. of years of the experiments conducted)

Yam bean *(Pachyrrhizus erosus)* cv. Rajendra Mishri Kanda-1 for tuber purpose at Phulbani

At Ranchi, hoeing by Dutch hoe in between rows of upland rice along with straw mulch gave additional grain yield of rice (493 kg/ha) compared to the control (750 kg/ha). While use of 3 cm of supplemental irrigation enhanced the productivity of rice by 415 kg/ha compared to the control. Straw mulch alone contributed for increase in yield by 343 kg/ha over no rainwater management practices.

3.1.4 Integrated nutrient management

In rice-horsegram cropping sequence at Phulbani, integrated supply of 30 kg N as chemical fertilizer and 30 kg N as FYM along with 40-40 kg P_2O_5 – K_2O recorded highest grain yield of

Table. 5. Influence of rain water management practices on productivity of pigeonpea and rice in Faizabad and Varanasi under rice based production system

Center	Crop	Treatment	Yield (kg/ha)	Mean over years
Faizabad	Pigeonpea (2)	Broadcasting	1714	1834
		Ridges and furrow sowing	2101	2116
		Line sowing with compartmental bunding	1918	2127
Varanasi	Rice (5) (Early sown)	Control	556	2025
		Straw mulch	750	2220
		10 kg N/ha (additional)	671	2263
		Dust mulch	556	2084
	Rice (5) (Late sown)	Control	544	1584
		Life saving irrigation	750	1807
		2% Urea spray	718	1806
		Reduction of plant population	567	1678

(Figures in Parentheses indicate no. of years of the experiments conducted)

Table. 6. Effect of drought management practices on productivity of upland rice at Ranchi and tomato in Phulbani

Center	Crop	Treatments	Yield (Kg/ha)	Gross returns (Rs/ha)
Phulbani	Tomato (Vegetable-crops) (1)	No pond (control)	19830	198300
		Lined pond with soil cement plaster 6:1 (8 cm thickness)	22830	228300
		Unlined pond	21330	213300
Ranchi	Upland rice (1)	Control	750	
		Hoeing by Dutch Hoe between rows + Leaf/straw mulching	1243	
		Application of 3 cm irrigation during dry spell	1165	
		Leaf/straw mulching	1093	

(Figures in Parentheses indicate no. of years of the experiments conducted)

rice (1365 kg/ha). There was no significant variation in the yield of rice between 30 kg N as FYM along with 20-20 P_2O_5 and K_2O per ha (1079 kg/ha) and 30 kg as chemical fertilizer + 30 kg N as glyricidia with 40-40 kg P_2O_5 and K_2O per ha (1048 kg/ha). These combinations on an average recorded higher grain yield of rice (212 kg/ha) as compared to 100% RDF (60-40-40 N-P_2O_5 and K_2O) **(Table 7).**

A maximum sole rice yield of 1400 kg/ha and sole blackgram yield of 488 kg/ha under sole crop blocks, and intercrop yields of 374 kg/ha of rice and 452 kg/ha of blackgram were attained under rice + black gram system with an application of 15 kg N as FYM + 20 kg N as inorganic fertilizer at Phulbani. The fertilizer application has given a maximum rice equivalent yield of 1814 kg/ha under intercropping system. The mean rice equivalent yield during 1998-2005 revealed that highest yield was obtained in sole back gram (2668 kg/ha), it is nearly double to rice + black gram system (1409 kg/ha) and 1394 kg/ha in sole rice.

At Phulbani, in greengram-mustard cropping sequence, the highest grain yield of green gram (377 kg/ha) was recorded with 5 t FYM per ha along with 20% of lime requirement, followed by lime @ 10% of LR + FYM @ 5 t/ha (306 kg/ha).

In pigeonpea + rice intercropping system at Phulbani, integrated supply of 20 kg N FYM + 25 kg N/ha through chemical fertilizer recorded highest rice equivalent yield (3277 kg/ha), followed 10 kg N through FYM + 35 kg N through chemical fertilizer (2925 kg/ha). Recommended N (45 kg/ha) as green leaf manuring performed equally with that of recommended dose of fertilizers with a combination of organic and inorganic sources. Based on 5 years results, a maximum mean yield of 3567 kg/ha was attained by 20 kg N (FYM) + 25 kg N (inorganic) fertilizer.

At Phulbani, the integrated nutrient supply system for Yam and maize intercropping system (1:2) showed 50% through chemical fertilizer + 50 percent N through FYM recorded a highest yam equivalent yield (14478 kg/ha) and gave yam yield of 12273 kg/ha and maize yield of 3677 kg/ha in the season and significantly to other nutrient supply combinations. The results over 4 years (2002-05) indicated that 50% through chemical fertilizer and 50 percent N through FYM recorded highest yam equivalent yield (10541 kg/ha) in intercropping system. These combinations on an average in intercropping system recorded additional yam equivalent yields of 7070 and 3820 kg/ha compared to the sole maize (3174 kg/ha) and yam (6431 kg/ha) with RDF respectively.

At Ranchi, in rice-black gram rotation system, 15 kg N through compost + 20 kg N through inorganic fertilizer recorded a highest grain yield of black gram (1180 kg/ha) and rice (1642 kg/ha) during 2005. Under rice + blackgram intercropping system at Ranchi, a maximum rice yield of 2157 kg/ha together with blackgram yield of 990 kg/ha were attained with an application of 100 percent recommended N through inorganic source (40 kg/ha). In rice-linseed system, use of 5 t/ha of FYM along with half RDF (20:15:10) kg NPK/ha recorded highest grain yield of rice (1654 kg/ha), followed by FYM @ 10 t/ha (1586 kg/ha). However, the *rabi* crop of linseed failed owing to poor germination during *rabi* 2005.

At Faizabad, use of 100% N recorded the highest grain yield in sole crops of maize (1443 kg/ha) and pigeonpea (1974 kg/ha). In case of maize + pigeonpea intercropping system, application of 100 percent recommended N gave a maize yield of 1067 kg/ha and pigeonpea yield of 1483 kg/ha.

The studies on influence of chemical fertilizers and organic manure on turmeric and black gram sequence at Phulbani indicated that use of 50% recommended dose of chemical fertilizer with a lime of 0.25 LR and FYM 20 t/ha recorded the highest grain equivalent yield of yam (972 kg/ha), followed by 50% RDF with FYM 20 t/ha, lime and bio-fertilizer (944 kg/ha). Liming the acid soil reduced the requirement of fertilizer N by 50%. On an average, 50% of RDF with lime (0.25 LR) and FYM (20 t/ha) recorded 72% higher yield of black gram over control (4119 kg/ha) **(Table 8).**

Table. 7. Effect of integrated nutrient management practices on productivity of different cropping systems under rice based production system

Center	Crop/cropping system	Treatment	Yield (kg/ha)		Mean over years		SYI	
			C1	C2	C1	C2	C1	C2
Faizabad	Maize + pigeonpea (5)	Control	392	1141	595	656	0.08	0.14
		100% recommended N	1067	1483	1224	1060	0.38	0.31
		50% recommended N	768	1158	948	718	0.25	0.16
		15 kg N (compost) + 20 kg N (urea)	703	1289	913	775	0.23	0.19
Phulbani	Pigeonpea + rice (5)	FYM @ 5 t/ha	358	778	510	778	0.18	0.12
		45 kg N/ha (urea)	417	1453	606	1576	0.17	0.52
		20 kg N (FYM) + 25 kg N	584	1842	785	1585	0.26	0.52
		10 kg N (FYM) + 35 kg N (urea)	504	1687	652	1490	0.20	0.48
Phulbani	Yam + maize (4)	Control	8273	2730	5211	1941	0.24	0.23
		80 kg N + 60 kg P + 80 kg K/ha	10564	3554	7489	3044	0.43	0.47
		50% N (urea) + 50% N (FYM)	12273	3677	8527	3507	0.51	0.57
		50% N (urea) + 50% N (green leaf)	10256	3628	8073	3279	0.48	0.52
Ranchi	Rice + blackgram (3)	Control	864	860	790	634	0.20	0.56
		40 kg N/ha (urea)	2157	990	1944	820	0.74	0.73
		15 kg N (compost) + 20 kg N/ha (urea)	2021	1085	1691	916	0.62	0.82
		25 kg N/ha (compost)	1626	1060	1348	875	0.46	0.78
Varanasi	Rice-lentil (5)	20 kg N/ha (Farmers' practice)	1591	88	2016	400	0.16	0.01
		100% RDF (inorganic)	2117	282	2547	618	0.30	0.14
		50% N (urea) + 50% N (FYM)	2442	216	2701	903	0.33	0.31
		100% organic manure (FYM)	2193	276	2570	906	0.30	0.31
Varanasi	Rice + greengram / lentil (5)	Control	3113	1173	1564	614	0.03	0.19
		100% RDF (inorganic)	1094	1240	2285	692	0.24	0.22
		15 kg N (greenleaf) + 20 kg N/ha (urea)	1459	1420	2274	728	0.21	0.26
		15 kg N (FYM) + 20 kg N/ha (greenleaf)	792	1307	1927	721	0.13	0.25
Phulbani	Rice + blackgram (2)	Control	159	117	188	146		
		60 kg N/ha	218	165	248	194		
		15 kg N/ha (FYM) + 20 kg N/ha (urea)	374	452	403	481		
		15 kg N/ha (green leaf) + 20 kg N/ha (urea)	355	213	384	242		

(Figures in Parentheses indicate no. of years of the experiments conducted)

(C indicates crop)

Table. 8. Effect of integrated nutrient management practices on productivity of different crops under rice based production system

Center	Crop	Treatment	Yield (kg/ha)	Mean over years	SYI
Faizabad	Chickpea (3)	Control	1164	1331	0.43
		Sulphur 30 kg/ha	1646	1972	0.71
		Sulphur 40 kg/ha	1587	1993	0.71
Phulbani	Rice (10)	Control	323	631	0.01
	(Rice-horsegram)	60 kg N + 40 kg P + 20 kg K/ha	852	1575	0.28
		30 kg N + 20 kg P + 20 kg K + 30 kg N/ha (FYM)	1365	1762	0.33
		30 kg N/ha (FYM) + 20 kg P + 20 kg K/ha	1079	1796	0.35
Phulbani	Rice (3)	FYM @ 5 t/ha	2250	1097	0.30
		60 kg N + 30 kg P + 30 K/ha + FYM @ 5 t/ha	3181	1988	0.56
		40 kg N + 20 kg P + 20 K/ha + FYM @ 5 t/ha	3377	1918	0.54
		20 kg N + 10 kg P + 10 K/ha + FYM @ 5 t/ha	2829	1599	0.45
Ranchi	Rice (9)	Control	647	399	0.09
	-Linseed*	40 kg N + 30 kg P + 20 kg K/ha	1340	1677	0.70
		FYM @ 5 t/ha + 20 kg N + 15 kg P + 10 kg K/ha (inorganic)	1654	1724	0.72
		FYM @ 10 t/ha	1586	1607	0.67
Varanasi	Lentil (3)	Control	399	917	0.21
	(Rice+greengram	100% RDF	290	1005	0.25
	-lentil)	15 kg N (greenleaf) + 20 kg N/ha (urea)	467	1432	0.45
		25 kg N/ha (FYM)	423	1353	0.41
Jorhat	Rice (1)	Control	2520		
		20 kg N + 20 kg P + 40 kg K/ha	3540		
		50% N (inorganic) + 50% N (organic)	4290		
		75% N (inorganic) + 25%N (organic)	3830		
Jagdalpur	Rice (1)	10 kg N/ha + FYM @ 2 t/ha	1900		
		80 kg N + 50 kg P + 30 kg K/ha	2033		
		BGA+60-50-30 kg/ha NPK	2413		
		Green leaf manuring-Sunhemp+ 60-40-10 Apply 7DB biasi)	2113		
Phulbani	Greengram (1)	Control	89		
	(Greengram-mustard)	20 kg N + 40 kg P + 20 kg K/ha	269		
		Lime @ 20% of lime requirement + FYM @ 5 t/ha	377		
		Lime @ 10% of lime requirement + FYM @ 5 t/ha	306		

* failed *(Figures in Parentheses indicate no. of years of the experiments conducted)*

At Varanasi, application of 50 percent N (inorganic) + 50 N (FYM) gave maximum rice yield of 2442 kg/ha in kharif, while 100 percent recommended fertilizer gave a lentil yield of 282 kg/ha in rabi season under rice-lentil system. An application of 15 kg N (green leaf) + 20 kg N (urea)/ha was superior for rice + greengram – lentil system with a yield of 1459, 1420 and 467 kg/ha in the study.

At Faizabad, application of 30 kg elemental sulphur recorded maximum grain yield in chickpea (1646 kg/ha), followed by 40 kg sulphur (1587 kg/ha). However, there was no significant difference in grain yield of chickpea among the sources of gypsum and elemental sulphur. At Jorhat, use of 50% N (inorganic) + 50% of N (organic) gave highest grain yield of rice 4290 kg/ha, followed by 75% of N inorganic with 25% of N organic (3830 kg/ha). Use of 50% N (inorganic) and 50% N (organic) gave 21% higher rice yield as compared to the recommended dose (3540 kg/ha). In Jagdalpur, use of blue green algae along with 60-50-30 kg NPK/ha recorded the highest grain yield of rice (2413 kg/ha), followed by green leaf manuring with sunhemp along with 60-40-10 kg NPK/ha (2113 kg/ha).

3.1.5 Tillage and nutrient management

The long term studies on tillage and nutrient management were conducted in different centers of rice based production system for the last 10 years. The salient findings of this study are as follows:

The conventional tillage gave a maximum yield of 2165 kg/ha, while low tillage + weedicide gave a minimum yield of 1991 kg/ha **(Table 9).**

Table. 9. Influence of tillage and nutrient management practices on productivity of different crops under rice based production system

Center	Crop/cropping system	Treatment	Yield (kg/ha)		Mean over years		SYI	
			C1	C2	C1	C2	C1	C2
Faizabad	Rice-Lentil (3)	Conventional tillage + 2 interculture	1498	1203	1758	1384	0.56	0.37
		Low till + 2 interculture	1282	1174	1541	1301	0.48	0.34
		Low till + weedicide + one interculture	1119	1185	1444	1268	0.45	0.32

(Figures in Parentheses indicate no. of years of the experiments conducted) (C indicates crops)

At Phulbani, the grain yield differences in rice-horsegram relay cropping system due to tillage management practices (conservation tillage + interculture, low tillage + interculture, low tillage + herbicide + interculture) were statistically on par. Among the tillage treatments, conventional tillage recorded highest grain yield (840 kg/ha). A combined analytical results (2001-06) indicated that conventional tillage + two interculture recorded highest rice equivalent yield (1462 kg/ha) followed by low tillage + interculture (1287 kg/ha), over 4 years.
At Faizabad, in rice-lentil system, conventional tillage + 2 hand weeding (20 and 40 DAS) together with 100 percent fertilizer N (organic) gave a highest seed yield of rice (1498 kg/ha), followed by low till + two hand weeding (20 and 40 DAS) (1282 kg/ha) and low till + one spraying of herbicide + one hand weeding (30 DAS) (1119 kg/ha). For lentil crop in *rabi* season, there was no significant difference in tillage treatments. Highest grain yield of lentil (1203 kg/ha) was recorded with conventional tillage.

At Ranchi for upland rice, off-season tillage + half conventional tillage + two hand weedings gave highest yield (564 kg/ha), followed by off-season tillage + half conventional tillage + weedicide + one hand weeding (549 kg/ha) and off-season tillage + conventional tillage + two hand weeding (521 kg/ha). In nutrient management, along with tillage, 50% through organic + 50% through inorganic gave highest rice yield of 669 kg/ha, followed by 100% through inorganic (505 kg/ha) and 100% through organic source (459 kg/ha). In *rabi* season for linseed, off-season tillage + half conventional tillage + weedicide + one hand weeding gave highest yield of 310 kg/ha, followed by off-season tillage + half conventional tillage + 2 hand weedings (280 kg/ha) and off-season tillage + conventional tillage + two hand weeding (222 kg/ha). In nutrient management systems use of nutrients through inorganic source registered the yield increment by 78 kg/ha compared to supply of nutrients through organic source only (230 kg/ha). To sum up, off-season tillage + conventional tillage along with both intra and inter weeding in combination with 100% nutrient supply through inorganic source recorded highest grain yield of lentil (369 kg/ha) among various combinations.

At Jagdalpur, summer ploughing + linseeding by Indira seed drill + seed rate @ 100 kg/ha + herbicide + green manure (sunhemp) recorded highest grain yield of rice (2293 kg/ha). **(Table 10).**

3.1.6 Crop management

At Ranchi, traditional practice of sowing of groundnut with Dutch hoe gave higher pod yield of 267 and 310 kg/ha compared to the sowing behind country plough and CRIDA Seed Drill respectively. The increment in the yield of groundnut is attributed with better germination with Dutch hoe compared to CRIDA Seed drill.

In Faizabad, sowing with Pantnagar Zero Till Drill gave highest lentil grain yield (1800 kg/ha), followed by Roto Til Drill (1649 kg/ha). Pantnagar Zero Till Drill gave a yield increase of 530 kg/ha over broadcasting. Roto Til Drill and Line sowing in lentil gave higher grain yield by 379 and 330 kg/ha respectively compared to the broadcasting (1270 kg/ha). Similar significant trends of results were noticed in respect of straw yield and harvest index. In maize, two times hand weeding at 20 and 40 DAS sowing gave highest grain yield (3364 kg/ha), followed by spray of Alachlor 2 kg a.i/ha pre-emergence along with one hand weeding at 30 DAS (3344 kg/ha) **(Table. 11).**

3.1.7 Alternate land use system and farming systems

The studies on establishment of different fruit trees in Marhan situation at Jagdalpur showed that aonla, pomegranate, cashew, guava and chickoo recorded 100% survival during 2005-06. Out of 8 species, drumstick recorded maximum height and canopy diameter in east-west direction. Lemon and Pomegranate

Fruit tree plantations at Jagdalpur

produced 22.5 and 11 branches per plant with 3.1 and 2.4 cm trunk girth respectively in Marahan conditions. In upland unbunded entisols with tikra micro farming systems, efforts were made to characterize the experimental site (Tikra) and Badi Marhan. Among these soils, Tikra has good soil depth and pH varied from 4.7 to 5.7 and EC 0.03 to 0.05 dsm^{-1}. The organic carbon (%) is found highest in top layer (0.52) and decreased towards increasing depth. Among fruit plants, the survival of aonla, cashew, guava and chickoo were found to be 100% whereas for drumstick it was lowest of 16 percent only. Maximum height among the plants was found in drumstick and canopy was highest in drumstick and also in mango.

At Varanasi, a site covering 1 ha was selected in Padri village in the block of Mirzapur, to develop sustainable model of rainfed Farming System interacting food, feed, fuel, timber, fruit and acqua organism for sustainable rainfed rural livelihood. The component crops were sown in a matching to physiographical situation and apportioned with strip/bund plantation at alternate crops. For example, areable crops (rice-chickpea/lentil/mustard, pigeonepa and sesame/rice/greengram) horticultural crops (Guava, Karonda, aonla, ber) were included in the model. The outer layer of the model was covered with Lasonia, teak and guava and inner layer was covered with *Leucaena*, lemon and sesbania. The vegetables (cowpea, okra, clusterbean, tomato and chillies were included as integral part of the module. While cattle and poultry and acqua-organisms (grass car and water nuts) were also raised in the system.

Table. 10. Influence of tillage and nutrient management practices on productivity of different crops under rice based production system

Center	Crop/cropping system	Treatment	Yield (kg/ha)	Mean over years	SYI
Phulbani	Rice (4)	Conventional tillage + interculture	840	1184	0.62
		Low till + interculture	732	952	0.47
		Low till + interculture + herbicide	802	974	0.49
	Horsegram (4)	Conventional tillage + interculture	152	231	0.38
		Low till + interculture	164	225	0.36
		Low till + interculture + herbicide	131	236	0.39
Ranchi	Rice (6)	Low tillage + 2 hand weeding	564	469	0.28
		Low tillage + Weedicide + 1 hand weeding	549	525	0.36
		off-season tillage + conventional tillage + 2 hand weeding	521	499	0.33
	Linseed (2)	Low tillage + 2 hand weeding	310	212	
		Low tillage + Weedicide + 1 hand weeding	280	204	
		off-season tillage + conventional tillage + 2 hand weeding	222	181	
	Groundnut (1)	Sowing with Dutch hoe	2008		
		Sowing behind country plough	1741		
		Sowing with CRIDA seed drill	1698		
Varanasi	Rice (4)	Conventional (2 disc harrowing + one cultivator)	2165	2428	0.22
		Low till (criss-cross cultivation + 2 interculture)	2116	2368	0.20
		Low till + herbicide	1991	2305	0.19
Jagdalpur	Rice (1)	Summer ploughing + line seeding by Indira seed drill + seed rate 100 kg/ha + herbicide + mechanical weeder	1160	—	—
		Summer ploughing + line seeding by Indira seed drill + seed rate 100 kg/ha + herbicide + green manure (sunhemp)	2293	—	—
		Summer ploughing + clot breaking + bushening along with N 30 + 150 kg seed rate, RDF(80-50-30) NPK/ha	2113	—	—
		Summer ploughing + clot breaking followed by ploughing with improved bushening + basal application (20+50+30) + Post Emergence weedicide	2000	—	—

(Figures in Parentheses indicate no. of years of the experiments conducted)

Table. 11. Influence of crop management practices on productivity of different crops under rice based production system

Center	Crop/cropping system	Treatment	Yield (kg/ha)	Mean over years	SYI
Faizabad	Lentil (3)	Broadcasting	1270	1487	0.52
		Pantnagar zero till drill	1800	2085	0.76
		Roto sowing	1649	1936	0.70
		Line sowing	1600	1875	0.68
	Barley (2)	Control	1426	1415	
		Planting 45 DAS	1329	1327	
		Cutting 60 DAS	1185	1387	
		Cutting 75 DAS	847	1026	

3.2 Maize Based Production System

3.2.1 Crops and varieties

The studies on screening of sesame cultivars at Arjia indicated that the cultivar RT-334 recorded highest seed yield (400 kg/ha), which was 22% higher over control RT-46. The combined results revealed that cultivar SPRT-23 gave highest mean yield (620 kg/ha), followed by SPRT-66 (600 kg/ha), which were 33 & 29% higher over check RT-46 (465 kg/ha). In horsegram, HG-50 matured in 60 days and suitable for erratic rainfall distribution. Among the cultivars, HG-1 gave highest seed yield (1036 kg/ha), followed by HG-20 (900 kg/ha) and HG-2 (887 kg/ha). The cultivar HG-17 gave highest fodder yield (3336 kg/ha), followed by HG-16 (2624 kg/ha). Varieties of AK-1 and AK-42 showed 11 and 17% increase in yield over check during 1999-2004. In sorghum, improved variety RC-2 (9162 kg/ha), CSV-15 (7750 kg/ha) and HC-308 (7713 kg/ha) showed promising results to achieve green fodder yield even in long dry spell experienced during the crop growth period. In black gram, ST-1-2 (1267 kg/ha), AU-4 (1181 kg/ha) and AU-3 (1181 kg/ha) recorded biological yield only due to low and erratic rainfall experienced during 2005-06. In taramira, the improved cultivars of PTM-1, TMCN-15 and PTM-2 recorded a grain yield of 1058, 929 and 917 kg/ha respectively in rainfed environment. In maize, Pratap Early Makka-3 was superior with a yield of 4167 kg/ha, followed by Navjot and PEHM-2 with an equal yield of 3906 kg/ha.

Sesame cv. SPRT-23 at Arjia

At Ballowal Saunkhri, the improved cultivars of PMH-2, JH-3459 and Prakash recorded cob yields of 4340, 4166 and 3985 per ha respectively.

At Rakh Dhiansar, wheat cultivars viz., PBW-527 (2228 kg/ha), WH-773 (2086 kg/ha) and PBW-299 (2068 kg/ha) recorded higher seed yield by 568, 426 and 408 kg/ha respectively compared to PBW-396 (1660 kg/ha) **(Table 12 and 13).**

3.2.2 Cropping systems

The studies on intercropping of blackgram in maize at Ballowal Saunkhri, maize (50 cm) + blackgram (1:1) recorded highest maize grain equivalent yield (3225 kg/ha). At Arjia, maize+blackgram and maize + groundnut recorded highest maize grain equivalent yields of 1441 and 1775 kg/ha in maize based cropping systems under rainfed environment. The combined results from 2000-04 recorded similar trends **(Table. 14).**

3.2.3 Rainwater management

At Arjia, the drought management studies in maize + blackgram recorded highest maize equivalent biological yield with protective irrigation (2915 kg/ha), followed by formation of ridges and furrows (2845 kg/ha) with delayed onset of monsoon. While planting of alternate crops of greengram, blackgram, sorghum + cowpea (fodder) and maize + blackgram (2:2) recorded maize equivalent biological yields of 4385, 3498, 6524 and 1913 kg/ha in rainfed environment. The results over the years (2000-04) indicated that planting of sesame, blackgram, greengram gave maize equivalent yields of 1651, 1562. and 1567 kg/ha respectively under delayed onset of monsoon. Among management practices, maize with normal seed rate, protective irrigation, formation of ridges and furrows and 25% higher seed rate produced maize equivalent grain yields of 1035, 1087, 985 and 951 kg/ha respectively under delayed onset of monsoon. The intra-plot water harvesting studies showed that ½ donar area with sorghum and ½ receiver area for maize produced highest maize biological equivalent yield, followed by 2/3 donar area for sorghum and 1/3 area of maize (3542 kg/ha). These systems on an average gave 29.5% higher maize biological equivalent yields compared to sole maize (2877

Table. 12. Influence of improved varieties on productivity of different crops in maize based production system

Center	Crop	Varieties	Yield (kg/ha) 2005-06	Yield (kg/ha) Mean over the years	SYI
Arjia	Sesame (7)	RT-333	191	412	0.19
		RT-46 (c)	315	465	0.24
		RT-334	400	376	0.15
		SPRT-23	383	620	0.39
R.Dhiansar	Wheat	PBW-396	1660	2099	0.25
		PBW-527	2228	2670	0.41
		WH-773	2086	2549	0.38
		PBW-299	2068	1738	0.14
Arjia	Maize	Local	3646	3646	0.69
		Navjot (c)	3906	2820	0.49
		Pratap early Makka – 3	4167	2370	0.38
		PEHM-2	3906	2465	0.40
B.Saunkhri	Maize (2)	Prakash	3985	3916	
		PMH-2	4340	4340	
		JH-3459	4166	3941	

(Figures in Parentheses indicate no. of years of the experiments conducted)

Table. 13. Influence of improved varieties on productivity of different crops in maize based production system

Center	Crop	Varieties	Yield (kg/ha)
Arjia	Horsegram	HG-29	608
		HG-1	1036
		HG-20	900
		HG-2	887
	Blackgram	Local	868
		ST-1-2	1267
		AU-4	1181
		AU-3	1181
	Taramira	TMCN-9	621
		PTM-1	1058
		TMCN-15	929
		PTM-2	917

Maize + blackgram (1:1) at Ballowal-Saunkhri

kg/ha). The full results of the study (2001-04) indicated that ½ donar (sorghum) + ½ receiver (maize) was the best *in situ* moisture conservation technology for getting higher yields of maize. Among fertility levels, 150 percent of RDG (MP) recorded higher maize equivalent yields (33.4%) compared to the control (1495 kg/ha). In another study, ridge sowing of maize, maize + blackgram, blackgram and groundnut recorded higher biological yield (3143 kg/ha), followed by flat sowing and ridging after interculture (2571 kg/ha), compartmental bunding at 5 m interval (2400 kg/ha) gave higher yields compared to the farmers' practice of seeding along the slope (1429 kg/ha). Ridge sowing as *in situ* conservation practice enhanced the productivity of crops by 120 percent compared to farmers' practice even in erratic distribution of rainfall year like 2005.

At Rakh Dhiansar, recommended dose of fertilizer (RDF) + life saving irrigation and RDF + mulch gave additional yield of maize by 146 and 71% respectively compared to control (704 kg/ha) under uneven distribution of rainfall with long dry spells like 2005. In maize on slopy lands mulch with sugarcane, subabool and basooti recorded higher grain yields by 44.4, 37.6, 18.2% respectively over control (2811 kg/ha). In *rabi* crops, there was no significant variation in yields of lentil, African sarson, and wheat due to mulches of sugarcane, basooti, *subabool* and also control. The influence of different crop residues on soil properties of pH, EC, Organic carbon and available N were statistically on par with maize as a test crop. In another study, supplemental irrigation of 5 cm depth based on irrigation water to pan evaporation ratios (IW/CPE of 0.3, 0.5 and 0.7) was applied in newly planted amla plants. During November 2005-June 2006, a total no. of 8, 12 and 14 irrigations were applied to amla plants grown with and without polythene mulch with irrigation levels of I-1, I-2 and I-3. Higher % increase in 10-diameter and plant height were recorded in mulch

Table. 14. Influence of cropping systems on productivity of different crops of maize based production system

Center	Crop/cropping system	Treatments/ system	Yield (kg/ha): 2005-06		Mean over years		SYI	
			C1	C2	C1	C2	C1	C2
B.Saunkhri	Maize + Blackgram	Maize (50 cm) + Blackgram (1:1)	1789	439	1812	464	0.66	0.47
		Maize (75 cm) + Blackgram (1:2)	1421	517	1349	563	0.49	0.57
		Maize (60 cm) + Blackgram (1:1)	1662	250	1688	417	0.62	0.42
		Maize (paired rows 45-60 cm) + Blackgram (1:1)	1681	242	1644	259	0.60	0.25
Arjia	Maize and other crops (4) (Maize eqt)	Maize – groundnut	1775		2286		0.03	
		Maize – blackgram	1441		1897		0.01	
		Maize – greengram	467		1806		0.01	
	Maize (5)	Maize – blackgram	2860		1868		0.33	
		Maize + blackgram – Maize	2711		2012		0.38	
		Maize – maize	2264		1777		0.30	

(Figures in Parentheses indicate no. of years of the experiments conducted)

(C indicates crop)

treatments where irrigation was applied at IW/CPE ratio of 0.07, followed by 0.05 and 0.03. In un-mulch treatments, the higher increase was noticed with IW/CPE ratio of –0.03, followed by 0.07 and 0.05. The trapezoidal trenches in amla not only helps to conserve the water and also help to check the loss of soil and water due to erosion. In Aloevera, no. of tillers were higher under mulch treatments compared to no mulch. A study of soil helped to conserve more moisture to get more no. of plants per hill. In rainfed lemon grass, soil stirring did not help to enhance the yields and oil content during kharif. While in *rabi*, soil stirring enhanced the oil yield by 132 kg/ha compared to the control.

At Ballowal Saunkhri, studies on contingency crop planning for different *rabi* crops indicated that sowing beyond second week of November reduced the yield in wheat, barley, lentil, taramira and African sarson, and raya by 82, 74, 100, 67 and 80% respectively.

In maize-wheat/raya/lentil cropping sequence, application of mulch of subabool, basooti and sugarcane trash helped in conservation of moisture to the extent of 21.5 to 21.9 cm over control (19.4 cm). The highest runoff was noticed in control and least under sugarcane mulch. Sugarcane mulch recorded highest crop productivity (4058 kg/ha), followed by subabool (3869 kg/ha), basooti (3323 kg/ha) and least under no mulch treatment (2811 kg/ha). Use of subabool and basooti mulches contributed for higher productivity by 38 and 18 percent respectively compared to no mulch, while sugarcane mulch has a higher productivity by 44 percent over control. The residual effects of mulched material used in *kharif* on productivity of *rabi* crops of wheat, African sarson and lentil was found significant. Use of mulch through crop residues has no influence on soil effects and electrical conductivity. But subabool mulch enhanced the content of organic carbon and also available nitrogen **(Table 15 and 16).**

Table. 15. Influence of rain water management practices on productivity and sustainable yield index in different cropping systems at Arjia

Crop/system	Treatments	Yield (kg/ha): 2005-06		Mean over years		SYI
		C1	C2	C1	C2	C1
Different crops (Maize eqt.)	Control (maize)	2429		1095		0.14
	Sorghum + cowpea (fodder)	10873		2267		0.41
	Greengram	4385		1335		0.19
	Blackgram	3498		1627		0.26
Maize + Blackgram (2)	Control	245	52	906	155	
	Supplemental irrigation	740	105	1342	189	
Groundnut + Sesame (2)	Control	745	67	934	85	
	Supplemental irrigation	1102	140	1299	123	

(Figures in Parentheses indicate no. of years of the experiments conducted) (C indicates crops)

Table. 16. Influence of rain water management practices on productivity of different crops in maize based production system

Center	Crop/system	Treatments	Yield (kg/ha): 2005-06	Mean over years	SYI
Arjia	Maize (3) (Maize equivalent.)	Control	2877	2335	0.19
		½ donar area	5644	3586	0.39
		1/3 donar area (sorghum)	5227	3160	0.32
Arjia	Maize	Farmers practice (sowing along the slope)	1429		
		Ridges & furrows	3143		
		Flat sowing & ridges after interculture	2571		
		Compartmental bunding (5m interval)	2400		
B.Saunkhri	Maize	Control	2811		
		Sugarcane mulch	4058		
		Subabul mulch	3869		
		Basoothi mulch	3323		

(Figures in Parentheses indicate no. of years of the experiments conducted)

3.2.4 Integrated nutrient management

The studies on maize + blackgram intercropping system at Rakh Dhiansar indicated that highest grain yield of sole maize (1907 kg/ha) was recorded with application of 100% recommended N through inorganic fertilizers followed by 15 kg N through green leaf along with 20 kg N through inorganic fertilizers (1614 kg/ha) and 15 kg through compost with 20 kg N through inorganic fertilizer (1601 kg/ha). In legume system (black gram), the highest maize equivalent yield was recorded with 15 kg N through green leaf and 20 kg N through inorganic fertilizers (794 kg/ha), followed by 15 kg N through compost and 20 kg N through inorganic fertilizers (709 kg/ha) and 25 kg N alone through compost (651 kg/ha). In cereal + legume (maize + blackgram) system, the highest maize equivalent yield was recorded with 100 % recommended N through inorganic fertilizers (1180 kg/ha) followed by 15 kg N through green leaf + 20 kg N through inorganic fertilizer (1009 kg/ha). Based on 6 years results (2001-05), 100 % recommended N through inorganic fertilizers recorded the highest maize equivalent yield in cereal (maize), legume (blackgram), and cereal + legume (maize + blackgram) systems.

At Arjia, the studies on Integrated Nutrient Supply System in cereal and legume blocks and strips indicated that maximum biological yield of maize was obtained in maize with 15 kg N through compost and 10 kg N through inorganic fertilizers (2465 kg/ha). While the biological yield of blackgram did not vary significantly in strips. In strips the highest maize biological yield was noticed with 15 kg N though compost and 10 kg N through inorganic fertilizer (2431 kg/ha). A combined result (2000-04) revealed that highest grain yield of maize and seed yield of blackgram was found with 15 kg N through compost with 10 kg N through inorganic fertilizer. The studies on nitrogen requirement of cereals in cereal-legume rotation indicated that the biological yield of maize was highest with maize + blackgram system (2816 kg/ha) closely followed by maize – maize + blackgram system (2711 kg/ha). Crop rotation of maize-maize reduced the maize grain yield by 21% compared to maize-blackgram system. Among nitrogen levels, there was no significant variation in grain yield of maize attained with 50, 75, and 100% of recommended nitrogen.

At Ballowal Saunkhri, application of 15 kg N through compost or 15 kg N (green leaf) together with 20 kg N/ha (inorganic) gave at par yield of maize with 100% recommended N through inorganic source (3759 kg/ha), thus saving 45 kg N/ha. The residual effect of various nutrient management practices applied to previous crop (blackgram) on the succeeding crop was studied and similar yield pattern was observed as in the case of wheat. In respect of wheat, 96 mm of rainfall was received. The crop experienced severe drought. Under this environment, application of nitrogen through organic or inorganic alone or in combination significantly increased the yield over control. In lentil, sown after blackgram where no nitrogen application was done, there was no variation in seed yield of lentil with different treatments. The soil data indicated that sources of nitrogen have no influence on soil pH, and electrical conductivity, build up of organic carbon content and available nitrogen content of the soil.

At Rakh Dhiansar, recommended dose of NPK (60:40:20 kg/ha) supplemented with 20 kg Z_n SO_4 recorded the highest grain yield (1976 kg/ha), closely followed by 100 percent of RDF alone (1848 kg/ha). The five years combined results (2001-05) revealed that recommended dose of NPK (60-40-20) coupled with 20 kg Z_n SO_4/ha recorded highest grain yield of maize (3058 kg/ha), closely followed by 100 percent RDF (2932 kg/ha). The percentage increase in grain yield of maize with RDF and 20 kg Zn SO_4/ha was to the tune of 104 compared to the control. In another study at Rakh Dhiansar, use of FYM @ 10 t and 40 kg N along with recommended P and K/ha gave highest grain yield of maize (1777 kg/ha). This is followed by FYM @ 10 t/ha + 30 kg N/ha + recommended PK (1569 kg/ha) and *Leucaena* leaves @ 5 t/ha and 30 kg N along with recommended P and K (1506 kg/ha). The previous seasons' results (2001-05) revealed that

use of FYM @ 10 t/ha along with 40 kg N/ha recorded highest grain yield of maize (2364/ha), followed by FYM @ 10 t/ha with 30 kg N/ha (2158 kg/ha). Use of organic manures of green manuring with nitrogen doses applied during *kharif* (maize) exhibited non-significant effect on grain yield of wheat. However, highest grain yield of wheat was recorded with 10 t of FYM and 40 kg N/ha (444 kg/ha), followed by FYM @ 10 t + 30 kg N/ha along with the recommended P and K (423 kg/ha). The combined result (2001-06) indicated that the highest mean grain yield of wheat was obtained with FYM @ 10 t/ha and 40 kg N/ha (1615 kg/ha) **(Table 17 and 18).**

3.2.5 Tillage and nutrient management

At Arjia, the test crop of blackgram experienced severe drought during 2005. Hence only biological yield of blackgram is reported. Conventional tillage along with two weeding and hoeings with 50% inorganic and 50% compost gave highest biological yield (520 kg/ha), followed by low tillage + herbicide + one hand weeding and hoeing with combination of organics and inorganics (430 kg/ha). But conventional tillage with different nutrient management practices recorded highest energy raising 2440-2570 MJ/ha during erratic rainfall year like 2005.

Table. 17. Influence of integrated nutrient management practices on productivity of different cropping systems of maize based production system

Center	Crop/ system	Treatments	Yield (kg/ha)		Mean over years		SYI	
			C1	C2	C1	C2	C1	C2
Arjia	Maize + blackgram (8)	Control	1736	312	1935	879	0.01	0.01
		100 % RDF	2187	417	2541	1081	0.05	0.01
		15 kg N (compost) + 10 kg N (urea)	2431	521	2806	1272	0.09	0.04
		15 kg N (greenleaf) + 10 kg N (urea)	2361	521	2758	1242	0.08	0.03
R.Dhiansar	Maize – wheat (5)	Control	694	305	1309	969	0.25	0.06
		FYM @ 10t/ha + 40 kg N/ha + Rec.PK	1777	444	2364	1650	0.55	0.35
		FYM @ 10 t/ha + 30 kg N/ha + rec.PK	1569	423	2158	1555	0.49	0.32
B.Saunkhri	Maize + blackgram (8)	Control	1690	458	1557	543 (2yrs)	0.30	
		100% RDF	3759	960	2841	983	0.64	
		15 kg N (compost) + 20 kg N (urea)	3556	850	2499	955	0.55	
		15 kg N (green leaf) + 20 kg N (urea)	3431	839	2490	916	0.55	

(Figures in Parentheses indicate no. of years of the experiments conducted) (C indicates crop)

Table.18. Influence of integrated nutrient management practices on productivity of different crops in maize based production system

Center	Crop/ system	Treatments	Yield (kg/ha)	Mean over years	SYI
R.Dhiansar	Maize + blackgram (Maize eqt) (8)	Control	403	1030	0.14
		100 % RDF	1180	2025	0.47
		15 kg N (greenleaf) + 20 kg N (urea)	1009	1723	0.37
		15 kg N (compost) + 20 kg N (urea)	982	1567	0.32
R.Dhiansar	Maize (10)	Control	683	1363	0.24
		Farmers practice (FYM @ 4t/ha+ 40 kg N as urea)	1534	2181	0.42
		100 % RDF (60 kg N + 40 kg P +20 kg K/ha)	1848	2932	0.58
		100% RDF + Zn SO4@ 20 kg/ha	1976	3058	0.61
		50% RDF+ 50% N (FYM)	1718	2551	0.50
R.Dhiansar	Maize (2)	Control	704	1019	
		100% RDF	1093	1511	
		100 % RDF + life saving irrigation	1731	2000	
		100% RDF + mulching	1204	1647	

The combined results (2001-04) revealed that conventional tillage with two weedings and hoeings in combination with 50% inorganic and 50% organic fertilizer gave positive trend to produce maize equivalent grain yields compared to other combinations. Similar trend of results was observed in respect of energy use over the years. The soil properties of organic carbon, bulk density and infiltration rate increased with the conventional tillage together with 100% organic source of nutrients.

At Ballowal Saunkhri, highest yield of maize was recorded with conventional tillage and interculture (2108 kg/ha) in maize-wheat sequence. This combination gave at par grain yield of maize with low tillage, interculture and chemical weed control together with 100 percent inorganic fertilizer (2016 kg/ha). In wheat, there is no significant variation in yield due to tillage treatments. However, use of 100% N through inorganic source recorded highest grain yield of wheat (1486 kg/ha), followed by combination of 50 percent organic and 50 percent inorganic fertilizer (1311 kg/ha) **(Table 19 and 20)**

Table. 19. Influence of tillage and nutrient management on productivity of maize-wheat at Rakh Dhiansar

Center	Crop	Treatments/ system	Yield (kg/ha)		Mean over years	
			C1	C2	C1	C2
R.Dhiansar	Maize - wheat	Low tillage + weedicide + interculture + 100 % inorganic	1859	698	1971	1928
		Conventional tillage + interculture + 100 % inorganic	1858	696	2051	1883
		Low tillage + interculture + 100 % inorganic	1925	673	1894	1817

(C indicates crop)

50% Conventional Tillage + interculture + chemical weed control in maize at Ballowal Saunkhri

50% organic + 50% inorganic (30.6 q/ha), at Ballowal Saunkhri

Table. 20. Influence of tillage and nutrient management practices on yield and sustainable yield index in maize and blackgram under maize based production system

Center	Crop	Treatments	Yield (kg/ha)	Mean over years	SYI
B Saunkhri	Maize	Conventional tillage + interculture + 100% inorganic	2108	2177	0.54
		Low tillage + interculture + weedicide + 100% inorganic	2016	2238	0.56
		Low tillage + interculture + 100% inorganic	1975	2095	0.51
Arjia	Blackgram	Conventional tillage + 2 intercultures + 50 % inorganic + 50% organic	520		
		Low tillage + herbicide + one interculture + 50% inorganic + 50% organic	430	680	
		Conventional tillage + 2 intercultures + 100 % inorganic	390		
		Low tillage + 2 intercultures + 50% inorganic + 50 % organic	380	431	

3.2.6 Alternate land use system and farming systems

At Rakh Dhiansar, the agroforestry options with green fodder in combination viz., guava, *Leucaena*, *Grewia optiva*, *Albizzia lebbek*, Aonla, and sole green fodder indicated that highest green fodder yield was noticed in sole fodder crop (20000 kg/ha), followed by aonla with green fodder (16500 kg/ha). Among various combinations, lowest fodder yield was noticed in guava + green fodder (12590 kg/ha) along with bonus yield of dry wood. The fruit yield of aonla was of the order of 3650 kg/ha. The results over four seasons (2002-05) revealed that highest average yield of green fodder was recorded in sole system (24690 kg/ha), followed by aonla + green fodder (22560 kg/

Aonla + Gobi Sarson at Rakh Dhiansar

ha). The average fruit yield of 2430 kg/ha in aonla was recorded along with green fodder. As a part of the farming system model, the arable crops viz., maize, wheat, blackgram/greengram-wheat, fodder-toria+gobi sarson, silvi-agri system i.e., *Leucaena* + fodder-wheat, agri-horti system i.e., Aonla + fodder + greengram / blackgram -Gobi sarson and vegetables and medicinal plants were implemented to augment the income of marginal and small farmers as a part of on-station program. In order to generate the technology on viable agro-forestry system for Jammu kandi region, an attempt was made with various combinations like agri-horti system, agri-silvi cultural system and agri-horti system along with agriculture alone during 2005. Among treatment combinations, Gobi sarson could not be sown in different treatments during *rabi* due to non-availability of soil moisture. In spite of drought year, both in terms quantity and distribution, highest yield of green leaves and fuel wood was noticed by 4511 and 2177 kg/ha in Gobi sarson and *Albejia lebbek* respectively. The average for four years revealed that highest yield of green leaves (5484 kg/ha) and fuel wood (3950 kg/ha) was recorded in the *Leucaena* and Gobi sarson system followed by *Albejia lebbek*. On an average, about 2430 kg/ha was harvested over the years in combination with Gobi sarson.

At Arjia, the studies in silvi-pasture system on marginal lands with varied trees in combination with bunding with MB Plough and chiseling with chisel plough indicated that bunding for various tree species on an average recorded a yield of 1784 kg/ha compared to chiseling (1606 kg/ha). Among tree species, *Acacia tortilis* and *Parkinsonia aculeate* recorded highest mean dry grass yield of 2065 and 1945 kg/ha respectively. The mean yields over 1987-2005 indicated that formation of bund in various fruit species enhanced the productivity of dry grass yield by 10 percent compared to chiseling (2150 kg/ha). In respect of tree species *Acacia tortills* produced the highest grass yield (2575 kg/ha), followed by *Piethocolovium dulce* (2327 kg/ha) and *Parkinsonia aculeate* (2261 kg/ha). In agri-horti systems, the arable crops in combination of pastures could not be established and also set the grains due to prolonged drought at reproductive stages of various crops. Among the pasture crops, *Cenchrus + stylo* recorded highest grass equivalent yield (4641 kg/ha).

At Arjia, in vegetable crops pumpkin grown with supplemental irrigation (5 cm) recorded 1791 kg/ha of maize equivalent yield. Among the moisture conservation practices, roto meter gave maximum maize equivalent yields of taramira (1280 kg/ha). In soil improvement practices, green manuring + gypsum application gave highest maize equivalent yield (1063 kg/ha) which was 31 percent higher over control/agriculture alone. Results over 2003-05 indicated that sesame recorded highest maize equivalent yield (2150 kg/ha), followed by maize (1653 kg/ha in field crops. Among vegetable crops, Pumpkin (1791 kg/ha) showed promising performance. In medicinal crops, Aswagandha and Sonamukhi recorded maize equivalent yields of 360 and 306 kg/ha respectively. Among pasture crops, *Stylosanthes hamata* and *Cenchrus+ Stylo* gave mean maize equivalent yield of 763 and 643 kg/ha.

In order to work out profitability of intercropping system in horti-based cropping systems, it is indicated that intercrop of blackgram gave highest grass equivalent yield (224.3 q/ha) compared to Cenchrus (2175 kg/ha). Formation of trench planting system (0.5 x 1 m) with 5 m horizontal interval recorded highest grain yield (3476 kg/ha). The results indicated that formation of trench with 5 m horizontal interval recorded highest grass equivalent yield (1541 kg/ha) and fruit yield in ber (2826 kg/ha), followed by trench with 10 m horizontal interval (2464 kg/ha). Planting of grasses and fruit trees at varied slopes had no influence on grass equivalent yield and also on fruit yield of ber. With in intercrops, highest grass equivalent yield was recorded with intercrop of balckgram (13933kg/ha). Highest ber yield was recorded with *cenchrus* as intercrop with ber (2783 kg/ha) followed by *cenchrus* and *stylo* (2193 kg/ha) **(Table. 21).**

Table. 21. Influence of alternate land use system on productivity of different crops in maize based production system

Center	Crop	Treatments	Yield (kg/ha)	Mean over years
Arjia	Silvipasture species	*Acacia tortilis* + bunding	2150	1825
		Parkinsonia aculeate + bunding	2050	1688
		Acacia tortilis + chiseling	1980	1715
		Prosopis juliflora + chiseling	1190	1232
R. Dhiansar	Gobi sarson and trees (green fodder)	Control (Gobi sarson)	20000	
		Aonla + gobi sarson	16500	
		Gravia optiva	14800	
		Guava + Gobi sarson	12590	

Center	Crop	Treatments	Yield (kg/ha)	Mean over years
R. Dhiansar	Trees and crops	*Leucaena* + fodder - wheat	21616	
		Fodder – toria + gobi sarson	21515	
		Aonla + fodder + blackgram – gobi sarson	21313	
		Maize – wheat (grain)	1737-625	
Arjia	Agrihorti based crops (Maize eqt.)	Pumpkin	1791	
		Stylosanthes hamata	763	
		Cenchrus + *Stylosanthes hamata*	643	
		Sesame	179	
B. Saunkhri	Lemon grass fresh yield (dry yield)	45 x 30 cm and mulching @ 6 t/ha	6920 (1797)	
		60 x 30 cm and mulching @ 6 t/ha	6788 (1745)	
		60 x 60 cm and no mulch	6140 (1517)	

3. 3. Oilseeds Based Production System

3.3.1 Groundnut based production system

3.3.1.1 Crops and varieties

Among seven genotypes of groundnut tested at Rajkot, JSP-40 was superior with a maximum yield of 2194 kg/ha. This is followed by GG-13C with a yield of 2102 kg/ha and JVR-449 with 2056 kg/ha. The genotypes had a low sustainability of 0.21 for M-335C to 0.60 for JVR-449. In a groundnut varietal trial with eight Virginia bunch varieties, a maximum pod yield of 1713 kg/ha was attained by JSSP-29. This was followed by JSSP-25 with a yield of 1602 kg/ha. These two genotypes had a sustainability of 0.50 and 0.35 in the last 6 years. In a varietal trial of season with eight genotypes, AT-93 was superior with a significantly higher yield of 739 kg/ha with a maximum sustainability of 0.76 in the last 5 years. Among ten genotypes of green gram evaluated, a maximum yield of 164 kg/ha was attained by RTM-10, while a minimum yield of 73 kg/ha was attained by GM-9926. The genotypes had a low sustainability ranging from 0.04 to 0.38 in the same period. In sorghum varietial trial with eight varieties, a maximum grain yield 634 kg/ha was attained by SR-2462, while a minimum yield of 309 kg/ha was attained by GJ-39. The varieties attained a mean yield of 440 kg/ha in the season. SR-1664 gave a maximum fodder yield of 7992 kg/ha, while SR-1657 gave a minimum fodder yield of 6140 kg/ha. The varieties attained a mean yield of 6676 kg/ha in the season **(Table. 22)**

Sesame cv GT-2 at Rajkot

3.3.1.2 Cropping systems

In a study on the use of small and shriveled seed of groundnut at Anantapur, the seed gave a higher yield compared to normal seed in 6 out of 9 farmers' fields. A yield in the range of 1322 to 2441 kg/ha was attained with small and shriveled seed compared to 1366 to 2206 kg/ha attained with normal seed.

Among different crop sequences tested together with integrated nutrient management practices at Rajkot, groundnut-groundnut was the best with maximum groundnut pod equivalent yield of 1246 kg/ha attained with 100 percent RDF. Castor-castor was the second best with a groundnut pod equivalent yield of 698 kg/ha with INM. Cotton-cotton gave minimum groundnut pod equivalent yield of 222 kg/ha **(Table. 23).**

3.3.1.3 Rainwater management

At Anantapur, a supplemental irrigation of 10 mm through sprinkler gave a relatively higher groundnut pod yield of 280 kg/ha. Compared to this, the farmers practice gave a yield of 200 kg/ha.

In an evaluation of size of bed at a grade for effective soil and water management with groundnut crop at Rajkot, control as per recommendation gave a maximum pod yield of 1040 kg/ha and fodder yield of 3340 kg/ha. A maximum fodder yield of 3300 kg/ha was attained with 30 cm distance between rows having 4 rows on broad bed of 120 cm and furrow of 60 cm **(Table. 24).**

3.3.1.4 Integrated nutrient management

In a long term INM study for groundnut at Anantapur under treated plots, application of 10 kg N + 20 kg P + 20 K kg/ha together with FYM @ 4 t/ha was superior with a yield of 1123

Table. 22. Influence of improved varieties on productivity at Rajkot

Center	Crop	Varieties	Yield (kg/ha)		SYI
			2005	Mean over years	
Rajkot	Groundnut	M-335-C	1343	1117	0.21
		JSP-40	2194	1785	0.49
		GG-13-C	2102	1812	0.50
		JVR-449	2056	2056	0.60
	Groundnut (6) (Virginia bunch)	Kadiri-3 (c)	870	860	0.12
		JSSP-29	1713		
		JSSP-25	1602	1385	0.35
		JVB-385	1574	1574	0.44
		JSSP-24	1481	1378	0.35
	Sesame (5)	AT-114	189	189	0.14
		AT-93	739	801	0.76
		AT-120	531	632	0.59
		G.Til-2 (c)	520	703	0.66
Rajkot	Greengram (4)	GM-9926	73	446	0.32
		RTM-10	164	164	0.09
		GM-4 (c)	143	526	0.38
		RTM-9	141	141	0.07
	Sorghum (2)	GJ-39	309	516	
		SR-2462	634	923	
		SR-1665	517	771	
		SR-1666	458	733	

(Figures in Parentheses indicate no. of years of the experiments conducted)

Table. 23. Influence of cropping systems on productivity of different crops of groundnut based production system

Center	Crop	Treatments/ system	Yield (kg/ha)	Mean over years
Rajkot	Crops (7) (Groundnut eqt.)	Groundnut – groundnut (RDF)	1246	891
		Cotton – cotton (RDF)	222	339
		Sesame – sesame (RDF)	376	772
		Pearl millet – pearl millet (INM)	452	455
		Castor – castor (INM)	698	591

(Figures in Parentheses indicate no. of years of the experiments conducted)

Table. 24. Influence of rain water management on productivity of groundnut at Anantapur and Rajkot

Center	Crop	Treatments/ system	Yield (kg/ha) : 2005	Mean over years
Anantapur	Groundnut (3)	Farmers' practice	200	238
		Water harvesting & supplemental irrigation of 10 mm through sprinkler	240	329
Rajkot	Groundnut (2)	Control (as per recommendation)	1040	1103
		30 cm distance between rows having 3 rows on broad bed of 90 cm and furrow of 45 cm	1008	1186
		30 cm distance between rows having 4 rows on broad bed of 120 cm and furrow of 60 cm	980	1143
		30 cm distance between rows having 2 rows on broad bed of 60 cm and furrow of 30 cm	977	1088

(Figures in Parentheses indicate no. of years of the experiments conducted)

kg/ha. Application of FYM @ 4 t/ha was the second best with a yield of 1009 kg/ha, while control gave a yield of 728 kg/ha in the season. The treatments had a sustainability of 0.22 to 0.35 for control and best treatment respectively.

In case of depletion plots, application of FYM @ 5 t/ha was superior with yield 958 kg/ha, while control gave a minimum yield of 677 kg/ha. The treatments had a sustainability in the range of 0.27 for control to 0.40 for application 10 kg N + 20 kg P +20 kg K/ha.

In pearl millet under permanent and rotational strips at Rajkot, application of 100 percent recommended N through inorganic fertilizer was superior under both strips, and gave a maximum grain yield of 1506 kg/ha under permanent strip, 1713 kg/ha under rotational strip compared to a sole crop yield of 1458 kg/ha, followed by application of 15 kg N (compost) + 15 kg N inorganic was the second best under permanent and sole crop plots with a yield of 1435 and 1319 kg/ha respectively. However, under rotational strip, 15 kg N (compost) + 20 kg N (inorganic) was superior with a yield of 1528 kg/ha. The treatments had a sustainability in the range of 0.21 to 0.48 under permanent strip, 0.27 to 0.47 under rotational strip 0.30 to 0.52 under sole crop block for control and 100 percent recommended N through inorganic fertilizer respectively.

Incase of integrated nutrient supply system study for groundnut under permanent, rotational strips and sole block at Rajkot, application of 25 kg N through compost was superior with a maximum yield of 1420 kg/ha under permanent strip and 2130 kg/ha under rotational strip. Under sole crop block, application of 100% recommended N through inorganic fertilizer gave a maximum yield of 2060 kg/ha. The different treatments had a low sustainability of 0.19 to 0.34 under permanent strip, 0.15 to 0.30 under rotational strip and 0.31 to 0.49 under sole crop block in the last 6 years.

In a study with 4 fertilizer treatments comprising of FYM, inorganic and vermi-compost for 6 crops at Rajkot, a maximum cowpea yield of 1944 kg/ha and 2222 kg/ha of groundnut were attained with an application of 50% of recommended fertilizer through inorganic source together with 0.5 t/ha of vermi compost. The treatment had a sustainability of 0.40 for cowpea and 0.38 for groundnut during the last 5 years.

Application of FYM @ 6 t/ha was superior for green gram and sesame with a yield of 509 and 417 kg/ha and sustainability of 0.54 and 0.60 respectively in the last 5 years. Incase black gram, application 100% recommended fertilizer through inorganic source was superior with a yield of 972 kg/ha and sustainability of 0.42 in the same period **(Table. 25).**

Table. 25. Influence of INM practices on productivity of different crops of groundnut at Anantapur and Rajkot

Center	Crop/System	Treatments	Yield (kg/ha) 2005	Mean over years	SYI
Anantapur	Groundnut (10) (Treated plots)	Control	728	682	0.22
		GRD (20 kg N + 40 kg P + 40 kg K/ha)	820	841	0.33
		10 kg N + 20 kg P + 20 kg K/ha + FYM @ 4 t/ha	1123	885	0.35
		FYM @ 4 t/ha	1009	824	0.31
	Groundnut (10) (Depletion plots)	Control	677	631	0.27
		GRD (20 kg N + 40 kg P + 40 kg K/ha)	750	761	0.37
		FYM @ 5 t/ha	958	738	0.35
		FYM @ 4 t/ha	918	764	0.37
Rajkot	Pearl millet (6) (Permanent)	Control	833	1053	0.21
		GRD (100% recommended N as urea)	1506	1731	0.48
		25 kg N/ha (compost)	1435	1539	0.40
		15 kg N (compost) + 10 kg N/ha (urea)	1435	1433	0.36
	Pearl millet (6) (Rotational)	Control	1065	1273	0.27
		GRD (100% recommended N as urea)	1713	1788	0.47
		15 kg N (compost) + 20 kg N/ha (urea)	1528	1498	0.36
		25 kg N/ha (compost)	1481	1445	0.34
Rajkot	Groundnut (6) (Permanent)	Control	895	999	0.23
		GRD (100% recommended N as urea)	1327	1121	0.29
		25 kg N/ha (compost)	1420	1224	0.34
		15 kg N (compost) + 10 kg N/ha (urea)	1327	1030	0.25
	Groundnut (6) (Rotational)	Control	1173	1025	0.15
		GRD (100% recommended N as urea)	1944	1396	0.30
		25 kg N/ha (compost)	2130	1366	0.28
		15 kg N (compost) + 10 kg N/ha (urea)	1821	1383	0.29

Center	Crop/System	Treatments	Yield (kg/ha) 2005	Mean over years	SYI
	Cowpea (5)	100% RDF	1805	853	0.40
		50% RDF + 0.5 t/ha vermi-compost	1944	870	0.40
		FYM @ 6 t/ha	1805	746	0.34
		Vermi-compost @ 1 t/ha	1574	779	0.36
	Green gram (5)	100% RDF	463	759	0.51
		FYM @ 6 t/ha	509	795	0.54
		50% RDF + 0.5 t/ha vermi-compost	463	791	0.54
		Vermi-compost @ 1 t/ha	417	738	0.50
	Blackgram (5)	100% RDF	972	1010	0.42
		FYM @ 6 t/ha	926	1077	0.46
		50% RDF + 0.5 t/ha vermi-compost	833	967	0.39
		Vermicompost @ 1 t/ha	741	816	0.30
	Sesame (5)	100% RDF	370	463	0.59
		FYM @ 6 t/ha	417	467	0.60
		50% RDF + 0.5 t/ha vermi-compost	324	465	0.60
		Vermi-compost @ 1 t/ha	278	329	0.40
	Groundnut (5)	100% RDF	1528	1349	0.31
		50% RDF + 0.5 t/ha vermi-compost	2222	1516	0.38
		FYM @ 6 t/ha	2037	1664	0.44
		Vermi-compost @ 1 t/ha	1852	1576	0.40

(Figures in Parentheses indicate no. of years of the experiments conducted)

3.3.1.5 Tillage and nutrient management

In an assessment of groundnut response to different tillage practices at Rajkot, a maximum pod yield 739 kg/ha and fodder yield 3322 kg/ha were attained when deep ploughing was done every year. A minimum pod yield of 667 kg/ha and fodder yield of 2956 kg/ha were attained with shallow ploughing.

In a tillage nutrient management study for sesame at Rajkot, a maximum seed yield of 199 kg/ha together with a fodder yield of 699 kg/ha were attained with low tillage combined with 100 percent inorganic fertilizer dose. However, a maximum fodder yield of 710 kg/ha together with a seed yield of 146 kg/ha were attained with low tillage combined with 100% organic fertilizer **(Table. 26).**

Table.26. Effect of tillage and nutrient management on seed yield of sesame at Rajkot

Tillage practices	Nutrient Management		
	100% organic source	100% inorganic source	50% organic + 50% inorganic
Conventional tillage	162	130	138
Low tillage + Interculture	199	88	146
Low tillage + Herbicide + interculture	146	130	99
Deep tillage up to 30 cm	140	128	128

3.3.1.6 Energy management

In a study on assessing the influence of mechanized inter-cultivation on groundnut yield at Anantapur, a maximum pod yield of 394 kg/ha and haulm yield of 1218 kg/ha were attained by inter-cultivation with tractor drawn implement twice at 25 and 40 DAS with 30x10 cm spacing. The farmer's method of inter-cultivation was the second best with 360 and 1174 kg/ha a pod and haulm yield respectively **(Table.27).**

3.3.1.7 Crop management

In a study with different crop sequences of sesame, groundnut, cotton, pearl millet and castor at Rajkot, a maximum fodder yield of 7083 kg/ha was attained with pearl millet-cotton system. This is followed by pearl millet-groundnut with 6875 kg/ha. The groundnut-groundnut system gave 2708 kg/ha, while sesame-sesame gave the lowest yield of 1227 kg/ha**.**

In a study on contingent planning with different *kharif* crops at Rajkot, pearl millet gave a maximum yield of 2833 kg/ha when sown on 16th June 2005, followed by 1859 kg/ha when sown on 29th June and 1475 kg/ha when sown on 3rd August 2005. Incase of sesame, a maximum yield of 384 kg/ha was attained when sown on either 29th June or 3rd August compared to 267 kg/ha when sown on 16th June 2005. Incase of black gram, the earliest date of sowing i.e. 16th June 2005 was the best with a yield of

1289 kg/ha followed by 29th June 2005 with 1036 kg/ha and 3rd August 2005 with 130 kg/ha. Incase of bunch groundnut, the same pattern of pearl millet and black gram was observed. A maximum pod yield 1900 kg/ha was attained when groundnut was sown on 16th June 2005, followed by 1667 kg/ha when sown on 29th June 2005 and 1159 kg/ha when sown on 3rd August 2005 **(Table. 28)**.

Among four dates of sowing tested for groundnut, sorghum, sunflower, pigeonpea, castor and clusterbean at Anantapur, the crops attained maximum yield when they were sown in the 1st fortnight of July. The yields attained were 203 kg/ha of clusterbean, 213 kg/ha of sunflower, 355 kg/ha of sorghum, 548 kg/ha of pigeonpea, 854 kg/ha of groundnut and 1195 kg/ha of castor. Sowing in second fortnight of June was the 2nd best, followed by second fortnight of July and first fortnight of August for different crops **(Table. 29).**

In a contingent planning study for long duration *kharif* crops at Rajkot, a maximum castor yield of 2058 kg/ha was attained when sown on 16th June 2005, followed by 1015 kg/ha when sown on 29th June 2005 and 617 kg/ha when sown on 3rd August 2005. Incase of cotton, the first date of sowing gave a kapas yield of 796 kg/ha, while the second date of sowing gave 62 kg/ha. Incase of pigeonpea, a maximum yield of 995 kg/ha was attained when sown on 16th June, 357 kg/ha when sown on 29th June and 82 kg/ha when sown on 3rd August 2005. Incase of spreading groundnut, the highest pod yield of 1955 kg/ha was attained when sown on 16th June, followed 1372 kg/ha when sown on 29th June and 720 kg/ha when sown 3rd August 2005 **(Table.30).**

Castor + groundnut (1:3) intercropping at Rajkot

Table. 27. Influence of energy management on productivity of different crops of maize based production system

Center	Crop	Treatments	Yield (kg/ha) 2005	Mean over years
Anantapur	Groundnut (2)	Farmers practice	360	640
		Intercultivation with tractor drawn implement twice at 25 & 40 DAS at 30 x 10 cm spacing	394	667
		Intercultivation with tractor drawn implement thrice at 25, 40 & 60 DAS at 30 x 10 cm spacing	344	612
		Intercultivation with tractor drawn implement twice at 25 & 40 DAS at 45 x 10 cm spacing	344	552

Table.28. Effect of time of sowing on the productivity and profitability of short duration crops at Rajkot

Date of sowing	Short duration crops			
	Pearlmillet	Sesame	Blackgram	Bunch groundnut
On set of monsoon (Normal) (16th June)	2833 (42984)	267 (9664)	1289 (31941)	1900 (44753)
15 days after on set of monsoon (29th June)	1859 (31674)	384 (3903)	1036 (25589)	1667 (38930)
30 days after on set of monsoon (3rd August)	1475 (20919)	384 (3567)	130 (3545)	1159 (26111)

Values in parentheses indicte gross monetary returns (Rs/ha)

Table.29. Influence of time of sowing on productivity of different crops at Anantapur

Treatments	Yield (kg/ha)					
	Groundnut	Sorghum	Sunflower	Pigeonpea	Castor	Clusterbean
Early sowing (June second fortnight)	379	259	121	594	672	142
Normal sowing (July first fortnight)	854	355	213	548	1195	203
Late sowing (July second fortnight)	420	315	115	259	503	120
Late sowing (Aug. first fortnight)	144	69	11	113	146	10

Table. 30. Effect of time of sowing on the productivity and profitability of long duration crops at Rajkot

Date of sowing	Long duration crops			
	Castor	Cotton	Pigeonpea	Spreading Groundnut
On set of monsoon (Normal)	2058 (30192)	796 (17003)	995 (17565)	1955 (48354)
15 days after on set of monsoon	1015 (14897)	583 (12469)	357 (6296)	1372 (31139)
30 days after on set of monsoon	617 (9053)	62 (1584)	82 (1687)	720 (16392)

3.3.1.8 Alternate land use system and farming systems

In an assessment of tree species lands for VI land capability at Anantapur, maximum stem girth of 36.8 cm on 5th July 2005 and 39.0 cm on 6th January 2006 were attained for tamrind in 9 x 9 m under plot with drip irrigation. Soap nut in 6 m x 6 m was the second best with 35.2 and 37.4 cm on the two dates respectively. In the plot with out drip irrigation, tamarind attained a maximum stem girth 26.5 and 28.1 cm, followed by soap nut with 24.8 and 27.7 cm on 5th July and 6th January respectively.

In an assessment of horti pasture systems groundnut + natural vegetation + tamarind with sheep component at Anantapur, a maximum net returns of Rs.9072/- per hectare was attained by growing groundnut. Compared to this, the horti-pastoral system gave negative returns of Rs.1273/- per hectare. However, the mean net returns attained from horti-pastoral system was higher at Rs.15290/- per hectare compared to groundnut with Rs.6536/-per hectare in the last two years **(Table. 31).**

Tamarind cv. PKM-1 under drip irrigation at Anantapur

Table.31. Influence of drip Irrigation on stem girth of different tree species at Anantapur

Tree species	With drip irrigation		Without drip irrigation	
	July 2005	January 2006	July 2005	January 2006
Soapnut	35.2	37.4	24.8	27.7
Tamarind	36.8	39.0	26.5	28.1
Custard apple	22.6	23.0	—	—
Ber	23.0	23.8	15.3	16.6

3.3.2. Soybean based production system

3.3.2.1 Crops and varieties

Among different crops evaluated at Rewa, lentil, linseed, and chickpea recorded the highest net returns of 9506, 6696 and 6648/ha. During *kharif*, a maximum mean yield of paddy was obtained (1550 kg/ha) with application of RDF 60 kg N and 40 kg P_2O_5/ha. During *rabi*, 100 percent RDF was found profitable under rainfed environment.

In greengram, TJM-15, which matures in 75 days, recorded highest grain yield (931 kg/ha) followed by HUM-1 (858 kg/ha), TM-99-50 (799 kg/ha) and TJM-47 (771 kg/ha). In respect of blackgram, IVU 486 (1313 kg/ha), IU-31-7 (1490 kg/ha) and IU-83-5 (1566 kg/ha) showed promising results in rainfed environment. In chickpea, JG 315 (1607 kg/ha), RWG-12 (1496 kg/ha) and JG322 (1593 kg/ha) recorded stability in yield under rainfed environment from 0.3 to 0.6. Out of 20 genotypes of lentil, RWL-4 gave highest grain yield (2200 kg/ha), followed by JL-2 (2041 kg/ha). L-9-49 gave lowest yield of 1178 kg/ha. The top two varieties had a sustainability of 0.57 and 0.56 for attaining a mean yield of 2151 and 2127 kg/ha in the last 5 years. However, L-9-49 was found to have the lowest sustainability of 0.41 for attaining a mean yield of 1669 kg/ha in the same period.

Among 20 varieties of chickpea evaluated at Rewa, JG-315 was superior with a yield of 1607 kg/ha, followed by JG-322 with 1593 kg/ha. Eleven varieties attained an above average yield in the range of 1270 to 1607 kg/ha, while 9 varieties attained in the range of 804 to 1219 kg/ha in the season. The varieties had a sustainability in the range of 0.26 (RWG-30) to 0.44 (RWG-12) in the last 10 years under dry sub-humid vertisols.

In an initial evaluation trial of linseed with 12 genotypes at Rewa, 2K-0106 was found to be superior with a grain yield 1296

kg/ha with a maximum sustainability of 0.63 for a mean yield of 950 kg/ha in the last 5 years. 2 K-0108 was the second best with a yield of 1130 kg/ha, while 2K-0101 was the third best with 1120 kg/ha. However, 2K-0101 attained a mean yield of 882 kg/ha with 0.58 sustainability, compared to 2K-0108 with a mean 823 kg/ha with 0.54 sustainability in the last 5 years. 2K-0105 attained lowest yield of 600 kg/ha in the season with a mean of 754 kg/ha and 0.49 sustainability in the last 5 years. In an advanced evaluation trial of linseed at Rewa, '50304' gave maximum yield of 1237 kg/ha, followed by '50302' with 1130 kg/ha.

At Indore, out of 9 niger genotypes, JNS-27 and JNS-10 were superior with a seed yield of 415 and 409 kg/ha respectively. Out of 9 varieties of soybean, a maximum seed yield of 2081 kg/ha was attained by JS-9305, followed by JS-335 with 1991 kg/ha. NRC-37 and Samrat were the third best varieties with a yield of 1965 kg/ha. The sustainability ranged from 0.37 for JS-9560 to 0.53 for JS-335 in the last 5 years. Out of 9 genotypes of pigeonpea evaluated, ICP-8863 was superior with a maximum yield of 1394 kg/ha. JIA-3D and JIA-30 were the second and third best entries with a yield of 1156 and 1109 kg/ha. It is observed that different genotypes had a low sustainability of 0.01 to 0.35, while only one variety had a moderate sustainability of 0.46 in the last 9 years **(Table. 32 and 33).**

Table. 32. Influence of improved varieties on productivity and sustainable yield index of different crops at Indore and Rewa

Center	Crop	Treatment	Yield (kg/ha)	Mean over years	SYI
Indore	Pigeonpea (9)	ICPL – 88039	666	484	0.01
		ICP – 8863 ©	1394	1522	0.46
		JIA – 3 (D)	1156	1276	0.35
		JIA – 30	1109	1138	0.29
		JIA – 60	938	1232	0.33
	Soybean (5)	JS 93-05	2081	1633	0.52
		JS-335	1991	1642	0.53
		Samrat	1965	1612	0.51
		NRC - 37	1965	1369	0.40
		JS-90-41	1902	1349	0.39
		JS 90-91	1875	1414	0.42
Rewa	Chickpea (10)	RWG – 36	804	1526	0.28
		JG 315	1607	2004	0.42
		JG 322	1593	2001	0.42
		RWG 12	1496	2064	0.44
		RWG 1	1478	1842	0.37
	Lentil (5)	L - 9- 49	1178	1669	0.41
		RWL 4	2200	2151	0.57
		JL 2	2041	2127	0.56
		LH 90 - 103	1992	2087	0.55
		RWL 9	1800	1956	0.51
	Linseed –IVT (5)	2K-0105	600	754	0.49
		2K-0106	1296	950	0.63
		2K-0108	1130	823	0.54
		2K-0101	1120	882	0.52
		2K-0107	1053	910	0.60

(Figures in Parentheses indicate no. of years of the experiments conducted)

Table. 33. Effect of improved varieties on productivity of different crops in soybean based production system

Center	Crop	Varieties	Yield (kg/ha)	Mean over years
Indore	Niger (2)	ONS – 150	162	162
		JNS – 27	415	415
		JNS – 10	409	409
		JNS – 26	389	392
		IGP – 76 (NC)	333	298
Rewa	Linseed (AVT)	50301	1098	
		50304	1237	
		50302	1130	
		50303	1114	
	Greengram	TJM 234	266	
		TJM 15	931	
		HUM 1 (c)	858	

Center	Crop	Varieties	Yield (kg/ha)	Mean over years
		TM 99-50	799	
		TJM 47	771	
	Blackgram	TU 17-4	591	
		IU 83-5	1566	
		IU 31-7	1490	
		IVU 486	1313	
		TU 98-43	1233	
	Chickpea	JGK 2004-325	257	
		JG 130	1278	
		MP JG 2001-12	1215	
		JG16	1181	
		JSC 6	903	

(Figures in Parentheses indicate no. of years of the experiments conducted)

3.3.2.2 Cropping systems

Pigeonpea (Bahar, NPWR-15 and Asha) + soybean (JS-335)/ cowpea, (Reshmi) Banarasi) intercropping at Rewa, Bahar gave a maximum pigeonpea yield of 2450 kg/ha together with a cowpea yield of 275 kg/ha. However, Asha gave a yield of 2433 kg/ha together with a soybean yield of 1172 kg/ha. The sole pigeonpea yield was in a range of 2333 to 2539 kg/ha, while sole soybean attained 2083 kg/ha and sole cowpea attained 500 kg/ha.

Among 7 crops evaluated for productivity and net profit at Indore, pigeonpea was superior with a grain yield of 1250 kg/ ha and a maximum net profit of Rs.13500/- per hectare with a maximum mean returns of 12735/- per hectare with a high sustainability of 0.81 in the last 4 years. This is followed by cotton with a net returns of Rs.10500/- per hectare with a mean of Rs.9125/- per hectare and sustainability of 0.73 in the last 4 years. Sorghum was unprofitable, while maize gave minimum net returns of Rs.1600/- per hectare with a sustainability of 0.80 under semi-arid vertisols.

Among different cropping systems evaluated at Indore under delayed onset conditions, a maximum soybean equivalent yield of 1849 kg/ha was attained from soybean + pigeonpea in 4:2 ratio when sown on 7th July. The system gave a yield of 1666 and 859 kg/ha when sown on 17th July and 27th July respectively. In an evaluation of different crops in *rabi* at Rewa, wheat attained a yield of 951 kg/ha, barley with 906 kg/ha, while lentil attained 732 kg/ha. Linseed gave a yield of 533 kg/ha, while mustard gave 259 kg/ha. Lentil gave a maximum net returns of Rs. 9506/ ha, while mustard gave lowest net returns of Rs. 1841/ha in the study **(Table.34).**

Table. 34. Influence of cropping systems on productivity of different crops under soybean based production system

Center	Cropping system	Treatment	Yield (kg/ha)	Mean over years
Rewa	Pigeonpea & other crops (6)	Pigeonpea (Asha)	2539	2247
		Pigeonpea (NPWR 15)	2333	2216
		Pigeonpea (Bahar)	2333	2142
		Soybean (JS 335)	2083	2166
		Cowpea (Reshmi Banarasi)	500	468
		Pigeonpea + Cowpea (1:2)	2450 + 275	3070
		Pigeonpea (Asha) + Soybean (1:2)	2433 + 1172	3391
		Pigeonpea (NPWR 15) + Soybean (1:2)	2333 + 906	3418
		Pigeonpea (NPWR 15) + Cowpea (1:2)	2317 + 300	3054
		Pigeonpea + Soybean (1:2)	2277 + 1111	3447
Indore	*Kharif* crops (4)	Maize	1800	1875
		Sorghum	1400	1750
		Soybean	1400	1238
		Groundnut	1320	1266
		Pigeonpea	1250	1150
		Cotton	1200	1038
		Safflower	945	945
Rewa	*Rabi* crops (4)	Mustard (c)	259	555
		Wheat	951	1542
		Barley	906	1359
		Lentil	732	987
		Linseed	533	767

(Figures in Parentheses indicate no. of years of the experiments conducted)

3.3.2.3 Rainwater management

In a study on judicious use of harvested water for *rabi* crops at Rewa, soybean attained a yield of 2512 kg/ha in the season compared to a mean of 1344 kg/ha in the last 5 years. Chickpea attained a yield of 810 kg/ha in the season against a mean of 1025 kg/ha in the same period. Methi and coriander yielded 658 and 31 kg/ha compared to a mean yield of 716 and 752 kg/ha respectively during the last 5 years.

In an on-station assessment of impact of conservation measures and water resources on soybean, wheat, chickpea and potato at Ringnodia watershed, large farmers attained a higher yield of 1600 kg/ha of soybean, while medium farmers attained higher yields of wheat (2800 kg/ha), chickpea (1200 kg/ha) and potato (16800 kg/ha). Small farmers got lower yield of crops.

Among different biological and mechanical barriers tested for erosion control at Indore, a maximum soybean yield of 2080 kg/ha was attained by sowing across the slope + growing rosha grass as a vegetative barrier. The lowest yield of 1480 kg/ha was attained when sowing was done along the slope. The lowest runoff 25.65 mm and a soil loss of 0.61 t/ha were provided when sown across the slope + rosha grass as a vegetative barrier. This had a maximum sustainability of 0.75 in the last 4 years for attaining a maximum mean yield of 1819 kg/ha. The control of sowing along the slope gave maximum runoff of 40 mm and soil loss of 3.79 t/ha and had a minimum sustainability of 0.53 in the same period.

Among different land configuration treatments tested for soybean under semi-arid vertisols of Indore, sowing under ridge and furrow system with 60 cm spacing was superior with a maximum yield of 1349 kg/ha, followed by sowing in 45 cm spacing with a yield 1261 kg/ha.

Among 6 types of mulches tested for soybean at Indore, polythene mulch was superior and gave grain yield 2024 kg/ha compared to no mulching with a yield of 1440 kg/ha. Glyricidia mulch @ 2 t/ha was the second best (1964 kg/ha), while weed bio-moss @ 5 t/ha was the third best with a yield of 1929 kg/ha **(Table.35).**

3.3.2.4 Integrated nutrient management

In a INM study with soybean and maize as sole crops and soybean + maize (4:4) as intercropping system under different blocks, combinations of N through urea, compost, green leaf manure and Azotobactor application were tested at Indore. In

Table.35. Influence of rain water management practices on productivity of different crops under soybean based production system

Center	Crop	Treatment	Yield (kg/ha)	Mean over years
Indore	Soybean (4)	Control (Sowing along the slope)	1480	1351
		Sowing across the slope + Veg. barriers (Rosha grass)	2080	1819
		Sowing along the slope + mechanical bund	1620	1543
		Sowing across the slope	1520	1472
Indore	Soybean (2)	Control (Sowing on flat bed at 45 cm)	820	755
		Ridge and furrow system (60 cm)	1349	1154
		Ridge and furrow system (45 cm)	1261	1146
		Broad bed and furrow system (45 cm)	1217	1072
		Back furrow after 10 m spacing (on flat bed)	1071	924
		Back furrow after 20 m spacing (on flat bed)	941	845
		Back furrow after 30 m spacing (on flat bed)	888	822
		Back furrow after 40 m spacing (on flat bed)	855	811
Rewa	*Rabi* crops (5) (Water harvesting)	Soybean	2512	1344
		Chickpea	810	1025
		Methi	658	716
Indore	Soybean	Control (no mulching)	1440	
		Polythene mulching	2024	
		Glyricidia leaves mulching @ 2t/ha	1964	
		Weed biomass @ 5t/ha	1929	
		Straw mulching @ 4t/ha	1905	
		Soil mulching	1786	
Rewa	*Kharif* crops (Contour levels)	Pigeonpea (Upper zone)	783	
		Blackgram (Middle zone)	458	
		Paddy (Lower zone)	2659	
	Rabi crops (Contour levels)	Lentil (Upper zone)	443	

(Figures in Parentheses indicate no. of years of the experiments conducted)

Straw and Polythene mulch in Soybean at Indore

maize block, a maximum maize yield of 3316 kg/ha was attained with 100 percent recommended N (urea), while 50% recommended N (urea) was the second best with a yield of 3031 kg/ha. These two treatments had a highest sustainability of 0.73 and 0.69 with a mean yield of 3440 kg/ha and 3288 kg/ha during the last 8 years.

In the soybean + maize intercropping block, a maximum soybean equivalent yield of 2285 kg/ha was attained with an application 100 percent recommended N (urea). The other INM treatments gave a significantly lower yield in the range of 1299 kg/ha (control) to 1978 kg/ha with an application 50 percent recommended N (urea). The superior treatment had a sustainability of 0.47 with a mean yield of 2412 kg/ha in the last 8 seasons, compared to the lowest of 0.24 sustainability with a mean yield of 1533 kg/ha for control.

In the long term manorial trial with different combinations of N and P levels, FYM and crop residue for soybean and safflower at Indore, application of FYM @ 6 t/ha + 20 kg N + 13 kg P/ha was superior with a soybean yield of 2234 kg/ha. The same treatments were superior for safflower with a maximum yield of 1354 kg/ha. The treatment had a high sustainability of 0.63 for soybean and moderate sustainability of 0.39 for safflower with a mean yields 1847 and 1479 kg/ha in the last 10 and 6 years respectively. Application of crop residue @ 5 t/ha + 20kg N + 13 kg P/ha was the second best with a yield of 2191 kg/ha of soybean and 1082 kg/ha of safflower with a moderate sustainability of 0.49 soybean in 10 years and low sustainability of 0.26 (safflower) in 6 years in the study. Control gave the lowest yield of 1481 kg with 0.3 sustainability for soybean and 527 kg/ha with 0.02 sustainability for safflower.

Among different INM treatments in soybean at Indore, application of 100 percent recommended N through urea was superior, with a yield of 1848 kg/ha. Application of 50 percent recommended N (1747 kg/ha), 15 kg N (compost) + 10 kg/ N (urea) with 1763 kg/ha and 15 kg N (compost) + 20 kg/ha (urea) with 1741 kg/ha were at par. The INM treatments had a sustainability ranging from 0.23 for control to 0.43 for 100% recommended N through urea during the last 8 years under semi-arid vertilsols.

In a P management study in soybean with combinations of Jabhua Rock Phosphate (JRP), PSM and FYM at Indore, a maximum seed yield of 2035 kg/ha was attained by JRP @ 60 kg P/ha + FYM @ 5t/ha. Single super phosphate @ 60 kg P/ha was the second best with a yield 1971 kg/ha. These two treatments had a sustainability of 0.66 and 0.62 in the last 6 seasons. Control gave the lowest yield 1154 kg/ha.

In a study with 4 treatments of organic and inorganic fertilizer + flat sowing + earthing at 25 DAS for maize at Indore, a maximum grain yield of 3782 kg/ha was attained by 50% recommended fertilizer though inorganic fertilizer and the remaining 50% through organic manure together with earthing on 25 DAS. The same treatment has given a maximum yield of 3408 kg/ha under flat sown. The control gave lowest yield of 2436 and 2254 kg/ha under earthing at 25 DAS and flat sowing treatments **(Table. 36)**.

Table.36. Influence of integrated nutrient management practices on productivity of different crops under soybean based production system

Center	Crop/cropping system	Treatment	Yield (kg/ha)	Mean over years	SYI
Indore	Soybean (8)	Control	1223	1153	0.23
		100% RD of N (urea)	1848	1658	0.43
		15 kg N (Compost) + 10 kg N (urea as top dress)	1763	1484	0.36
		50% RD of N (urea)	1747	1639	0.42
		15 kg N (Compost) + 20 kg N (urea as top dress)	1741	1458	0.35
		15 kg N (Compost) + 10 kg N (green leaf) + 10 kg N (urea as top dress)	1667	1518	0.37
		15 kg N (green leaf) + 20 kg N (urea as top dress)	1667	1465	0.35
		15 kg N (green leaf) + 10 kg N (urea as top dress)	1645	1504	0.37

Center	Crop/cropping system	Treatment	Yield (kg/ha)	Mean over years	SYI
Indore	Maize (8)	Control	2063	2073	0.41
		100% RD of N (urea)	3316	3440	0.73
		50% RD of N (urea)	3031	3288	0.69
		15 kg N (Compost) + 10 kg N (green leaf) + 10 kg N (urea as top dress)	2895	3061	0.64
		25 kg N/ha (Compost)	2815	2865	0.59
		15 kg N (compost) + 10 kg N (urea as top dress)	2758	2767	0.57
		25 kg N Compost + 15 kg N (urea as top dress)	2596	3005	0.63
		15 kg N (green leaf) + 10 kg N (urea as top dress)	2564	2758	0.57
	Soybean + Maize (SEY) (8)	Control	1299	1533	0.24
		100% RD of N (urea)	2285	2412	0.47
		50% RD of N (urea)	1978	2140	0.40
		25 kg N/ha (Compost)	1784	1973	0.35
		15 kg N (Compost) + 20 kg N (urea as top dress)	1783	2012	0.36
		25 kg N Compost + 15 kg N (urea as top dress)	1614	1971	0.35
		15 kg N (Compost) + 10 kg N (green leaf) + 10 kg N (urea as top dress)	1604	1888	0.33
		15 kg N (Compost) + 10 kg N (green leaf)	1582	1959	0.35
	Soybean (10)	Control (N0 P0)	1481	1073	0.30
		FYM 6t/ha + N20 P13 (FYM in rainy season only) + N20 P13 to each crop	2234	1847	0.63
		Residue 5t/ha + N20 P13 to each crop	2191	1519	0.49
		N60 P35 to each crop	2089	1713	0.57
		FYM @6t/ha in rainy season	1944	1571	0.51
		Residue 5t/ha (CR of Soybean/safflower to each crop)	1811	1384	0.43
		N40 P26 to each crop	1788	1596	0.52
		N30 P20 to each crop	1649	1496	0.48
	Safflower (6)	Control	527	646	0.02
		FYM 6t/ha + N20 P13 (FYM in rainy season only + N20 P13 to each crop)	1354	1479	0.39
		Residue 5t/ha + N20 P13 to each crop	1082	1193	0.26
		N60 P35 to each crop	1047	1188	0.26
		FYM @6t/ha in rainy season	1030	1151	0.24
		N40 P26 to each crop	955	1161	0.25
		Residue 5t/ha (CR of Soybean/safflower to each crop)	909	1058	0.20
		N30 P20 to each crop	833	1015	0.18
Indore	Soybean (6)	Control	1154	1185	0.44
		P60 (JRP) + 5t/ha FYM	2035	1653	0.66
		P60 (SSP)	1971	1571	0.62
		P60 (JRP) + 5t/ha FYM + 10g PSM/hg seed treatment	1891	1583	0.63
		P60 (JRP) + 5t/ha FYM + 10g PSM/hg seed treatment+ 3kg PSM blended with 50 kg FYM/ha	1843	1631	0.65
		P60 (JRP)	1827	1448	0.56
		P60 (JRP) + 3 kg PSM blended with 50 kg FYM/ha and broadcasted	1827	1452	0.57
		P60 (JRP) + 10g PSM/kg seed treatments	1827	1447	0.56

Center	Crop/cropping system	Treatment	Yield (kg/ha)	Mean over years	SYI
Rewa	Rice-Wheat (5) (Chickpea Eqt.)	Control	730	994	0.21
		100% RD of N through compost	1146	1520	0.46
		50% N through fert. +50% N through compost + Azotobacter	1031	1469	0.44
		25% RD of N through fert. +50% N through compost + Azotobacter	1022	1403	0.41
		25% N through fert. + 50% N through compost	988	1425	0.42
		50% RD of N through fert. +50% N through compost	962	1376	0.39
		50% RD of N through fert. +25% N through compost + Azotobacter	962	1358	0.39
		50% RD of N through fert. +25% N through compost	937	1337	0.38
	Blackgram-chickpea (5) (Chickpea Eqt.)	Control	686	916	0.33
		100% RD of N through compost	922	1536	0.60
		25% RD of N through fert. + 50% N through compost + Azotobacter	855	1423	0.55
		50% N through fert. + 25% N through compost + Azotobacter	829	1311	0.50
		50% N through fert. + 50% N through compost + Azotobacter	824	1401	0.54
		25% N through fert. + 50% N through compost	788	1399	0.54
		50% RD of N through fert. + 50% N through compost	773	1311	0.50
		50% RD of N through fert. + 25% N through compost	768	1233	0.47
	Wheat/chickpea (5) (Chickpea Eqt.)	Control	643	858	0.23
		100% RD of N through compost	1027	1586	0.56
		25% Rd of N through fert. + 50% N through compost + Azotobacter	974	1467	0.50
		50% N through fert. + 50% N through compost + Azotobacter	943	1450	0.49
		25% N through fert. + 50% N through compost	903	1414	0.48
		50% RD of N through fert. + 50% N through compost	873	1359	0.45
		50% RD of N through fert. + 25% N through compost + Azotobacter	863	1313	0.43
		50% RD of N through fert. + 25% N through compost	846	1273	0.42
	Rice (3)	Control	927	1245	0.07
		100% NPK + secondary and micronutrients	1218	1909	0.30
		50% Rec. NPK + 50% N as FYM	1090	1684	0.22
		50% N as FYM/Other organic sources + biofertilizer + rock phosphate	1054	1614	0.20
		T2 + biofertilizer containing N and P carriers	1018	1581	0.19
		Different organic sources each eqt. To 1/3 of rec. N (FYM + Vermi compost + non edilble oil cake)	981	1537	0.17
		T2 + interculture	979	1459	0.15
		T2 + agronomic practices for weed and pest control	954	1378	0.12
	Mustard	Control	724		
		20 kg N/ha	937		
		40 kg N/ha	1132		
		60 kg N/ha	1180		
Indore	Maize	Control + Flat sowing	2254		
		50% RDF + Earthing 25 DAS	3782		
		100% RDF + Earthing 25 DAS	3494		
		10t/ha OM + Earthing 25 DAS	3312		
		10t/ha OM + Flat sowing	3162		
		100% RDF + Flat sowing	3154		
		Control + Earthing 25 DAS	2436		

(Figures in Parentheses indicate no. of years of the experiments conducted)

In rice-wheat sequence with different INM treatments at Rewa, 100 percent recommended N through compost was gave highest chickpea equivalent yield of 1146 kg/ha and was superior with maximum chickpea equivalent yield of 922 kg/ha under blackgram-chickpea sequence and 1027 kg/ha under wheat chickpea sequence. The treatment had a moderate sustainability in the range of 0.46 under rice-wheat to 0.60 under blackgram-chickpea sequence in the last 5 years. Application of 100 percent NPK + secondary and micronutrients was superior for rice with a yield of 1218 kg/ha at Rewa. In case of mustard at Rewa, application of 40 and 60 kg N/ha were at par with a yield of 1132 and 1180 kg/ha.

3.3.2.5 Tillage and nutrient management

In tillage and fertilizer management study with soybean at Rewa, low till + weedicide + interculture was superior with a maximum seed yield of 2670 kg/ha, while low till interculture gave lowest yield of 2105 kg/ha. The treatments had a sustainability of 0.44 and 0.27 for attaining a mean yield of 1910 and 1401 kg/ha respectively in the last 6 years. Among fertilizers, application of 50 percent through organic source + and the remaining 50 percent through inorganic source was superior with a maximum yield of 2636 kg/ha in the season, with a maximum mean yield of 2636 kg/ha in the season. With a maximum mean yield of 1891 kg/ha sustainability of 0.44 in the last 6 years. Application of 100 percent through organic source, i.e, FYM @ 8 t/ha gave lowest yield of 2292 kg/ha in the season, while it had a mean of 1537 kg/ha and 0.32 sustainability in the same period.

Among different combinations tillage, organic and inorganic fertilizer for soybean at Indore, low tillage + straw @ 4 t/ha + hand weeding was superior with the highest yield of 1270 kg/ha having 0.44 sustainability. The lowest yield of 833 kg/ha was attained by low tillage + glyricidia @ 2 t/ha + herbicide with a sustainability 0.28 **(Table. 37).**

3.3.2.6 Energy management

At Indore, among 3 seeding implements tested for soybean, sowing with CRIDA planter gave a maximum grain yield of 1725 kg/ha. Tifan was the second best with a yield of 1596 kg/ha, while Duphan gave a minimum 1418 kg/ha in the season **(Table. 38).**

3.3.2.7 Alternate land use system and farming systems

Among different combinations of fruit trees and crops evaluated under agro-horti system at Indore, a maximum soybean equivalent yield of 693 kg/ha was attained by amla + pigeonpea system. This was followed by drumstic + soybean + pigeonpea with a yield of 653 kg/ha. The different combinations had a low sustainability of 0.02 to 0.17 in the last 6 years **(Table. 39).**

Table. 37. Influence of tillage and nutrient management practices on productivity of different crops under soybean based production system

Center	Crop/cropping system	Treatment	Yield (kg/ha)	Mean over years	SYI
Indore	Soybean (7)	CT + RF – OST + HW	860	1314	0.38
		LT + 4t/ha Straw + HW	1270	1442	0.44
		LT + 4t/ha Straw + Hb	1098	1169	0.31
		LT + 4t/ha Compost + HW	1074	1415	0.43
		LT + 4t/ha Compost + Hb	926	1176	0.31
		LT + 2t/ha Glyricidia Greenleaf + HW	903	1381	0.41
		CT + RF + OST + HW	850	1528	0.48
		LT + 2t/ha Glyricidia Greenleaf + Hb	833	1103	0.28
Rewa	Soybean (6)	**Tillage**			
		Low till + Weedicide + Interculture	2670	1910	0.42
		Conventional tillage (CT) + Interculture	2484	1748	0.39
		Low till (50% of CT) + Interculture	2105	1401	0.27
		Fertilizer			
		50% organic + 50% Inorganic	2636	1891	0.44
		100% Inorganic	2392	1685	0.37
		100% of organic source (8t FYM or OM/ha)	2292	1537	0.32

(Figures in Parentheses indicate no. of years of the experiments conducted)

CT = Conventional tillage; LT = Low tillage; HW = Hand weeding; Hb = Herbicide; OST-off season tillage RF-Recommended Fertilizer

Table. 38. Influence of energy management practices on productivity of soybean

Center	Crop	Treatment	Yield (kg/ha)
Indore	Soybean	Sowing with Duphan	1418
		Sowing with Tifan	1596
		Sowing with CRIDA planter	1725

Table.39. Effect of agri-horti. system on yield of different components at Indore

Center	Crop/cropping system	Treatment	Yield (kg/ha)		Mean over years	
			SY*	SEY**	SY	SEY
Indore	Agro- horti system (6)	Awalan + Cowpea	43	67	165	229
		Awalan + Soybean	583	635	1067	1262
		Drumstick + Soybean	519	564	1038	1230
		Ber + Soybean	440	483	918	1084
		Awalan + Pigeonpea	398	633	912	1706
		Drumstick + soybean + pigeonpea (4:2)	287+ 194	693 653	583+ 424	1495

(Figures in Parentheses indicate no. of years of the experiments conducted)

* Soybean yield ; ** Soybean equivalent yield

3.3.2.8 Crop management

In an evaluation of suitability of different crops and cropping systems, the different three dates of sowing at Indore, a maximum soybean equivalent yield was attained on first day of sowing for sole soybean (1949 kg/ha), sole pigeonpea (2454 kg/ha), soybean + pigeonpea (2616 kg/ha), sunflower + pigeonepa (2388 kg/ha) and cowpea + pigeonpea (1240 kg/ha). When sown on second day, sole sunflower gave a maximum soybean equivalent yield of 2092 kg/ha, sole cowpea gave 359 kg/ha and soybean + sunflower gave 2244 kg/ha. The study indicated that soybean + pigeonpea was the best system that could be sown on first day of sowing with a maximum soybean equivalent yield of 2616 kg/ha **(Table. 40).**

Table.40. Effect of dates of sowing on productivity of soybean, sunflower, pigeonpea and cowpea in sole and intercropping systems

Center	Crop/cropping system	Treatment	Yield (kg/ha)		Mean over years
Indore	Sole Soybean	07.07.05 (D1)	1632		1949
		17.07.05 (D2)	1111		1371
		27.07.05 (D3)	937		1158
	Sole Sunflower	07.07.05 (D1)	1146		1793
		17.07.05 (D2)	1337		2092
		27.07.05 (D3)	9555		1495
	Sole Pigeonpea	07.07.05 (D1)	1354		2454
		17.07.05 (D2)	1033		1867
		27.07.05 (D3)	799		1470
	Sole Cowpea	07.07.05 (D1)	177		277
		17.07.05 (D2)	229		359
		27.07.05 (D3)	177		277
	Soybean + Pigeonpea (4:2)	07.07.05 (D1)	1215	634	2616
		17.07.05 (D2)	1076	590	2397
		27.07.05 (D3)	425	434	1388
	Sunflower + Pigeonpea (4:2)	07.07.05 (D1)	634	602	2388
		17.07.05 (D2)	903	477	2275
		27.07.05 (D3)	477	399	1484
	Cowpea + Pigeonpea (4:2)	07.07.05 (D1)	120	582	1240
		17.07.05 (D2)	135	538	1183
		27.07.05 (D3)	113	469	1040
	Soybean + Sunflower (4:2)	07.07.05 (D1)	642	781	1933
		17.07.05 (D2)	920	677	2244
		27.07.05 (D3)	347	365	990

(Figures in Parentheses indicate no. of years of the experiments conducted)

3.4 Cotton Based Production System

3.4.1 Crops and varieties

At Kovilpatti, the entries of KWA-23 of *Gossipium arboreum* recorded maximum seed yield of cotton (647 kg/ha), which was 6% higher over local checks (K-11) (613 kg/ha). The culture CINA 318 and GAM 93 recorded highest ginning outturn of 40%. Among Desi hybrids, the hybrid AAH-21 recorded the lowest days for 50% flowering, while hybrids AKDH-33, CISAA-8 and JKCDH-501 recorded more number of bolls. Among the entries, JKCDH-501 gave the kapas yield of 613 kg/ha. In *Gossypium hirsutum* cotton, CPD-758 recorded highest ginning outturn (38%), while cotton cultures L-763, ARB 782 and CPD 03-2 recorded the highest yield. In sunflower, AHT 8 recorded highest seed yield (1540 kg/ha), followed by AHT 4 (1130 kg/ha). In a multilocation trial of sunflower, the entry '503' gave a yield of 1243 kg/ha in the season **(Table.41).**

3.4.2 Cropping systems

At Akola, among different dwarf pigeonpea varieties tested in combination with cotton + pigeonpea, C-11 recorded highest gross monetary returns (Rs.39880/ha), followed by cotton + pigeonpea (ICP-8863), which gave gross monetary returns of Rs.36260/ha. Cotton + pigeon pea (C-11) recorded highest cotton seed equivalent yield (2169 kg/ha), while cotton + pigeonpea system gave the lowest seed equivalent yield (1625 kg/ha). Soybean-chickpea (PKV Kab-2) registered highest soybean grain equivalent yield (4658 kg/ha) and gross monetary returns (Rs. 53849/ha), followed by soybean-chickpea (ICCV-2) with 4000 kg/ha of soybean equivalent yield and Rs. 46311/ha of gross monetary returns. Among the varieties of chickpea, PKV Kab-2 recorded highest grain yield, followed by AKG-46 and ICCV-2. In respect of mustard, ACN-9 and Pusa bold produced at par yield during *rabi* season **(Table.42).**

Table.41. Influence of improved varieties on productivity in cotton based production system

Center	Crop	Varieties	Yield (kg/ha)
Kovilpatti	*Gossypium arboreum* cotton (Coordinated varietal trial)	Local (K 11)	613
		KWA 23	647
		JLA-2199	263
		GAM-124	573
		ZC (DLSA 17)	647
		DLSA 201	622
	Gossypium arboreum cotton (Desi hybrid trial)	Local (K 11)	533
		AAH-1 (CC)	297
		JKCDH - 501	613
		AKDH 33	573
		CISAA 8	553
		CISAA 7	503
	Gossypium hirsutum cotton	RAH-11	263
		L 763	487
		ARB 782	393
		CPD 03-2	388
		CNH-03	362
		RAH-4	340
	Gossypium hirsutum cotton	KC 2 (LC)	860
		CPD-758	388
		KH 138	768
		SCS 101	647
		RAH 30	640
		ARB-757	590
	Sunflower (Initial Hybrid Trial)	K1 (c)	872
		685	1556
		681	1392
		684	1166
		682	1054
		678	1028
	Sunflower (Advanced Hybrid Trial)	K1 (c)	739
		AHT 8	1540
		AHT 4	1130
		AHT 5	1026
		AHT-7	992
		AHT-6	935
	Sunflower (Multi-location trial)	K1 (c)	378
		503	1243
		502	1089
		504	915
		501	606

Table.42. Influence of cropping systems on productivity of different crops in cotton based production system

Center	Crop	Treatments/ system	Yield (kg/ha)		Mean over years	
			1	2	1	2
Akola	Soybean (4) – chickpea/ mustard(3)	Soybean (JS-335) – chickpea (PKV.KAB 2)	2700	899	1851	1008
		Soybean (JS-335) – chickpea (ICCV-2)	2762	573	1766	824
		Soybean (JS-335) – chickpea (AKG-46)	2755	771	1842	1041
		Soybean – mustard (Pusa bold)	2706	511	1849	408
Akola	Cotton + pigeonpea (2)	Cotton + pigeonpea (C11)	635	1599	375	1073
		Cotton + pigeonpea (ICP-8863)	549	1432	337	1046
		Cotton + pigeonpea (AKT-8811)	582	1397	354	1077
		Cotton + pigeonpea (222492-97)	613	1054	382	851
Parbhani	Different crops	Soybean (MAUS-71) + pigeonpea (BSMR-853)(4:2) (sowing on 28th SMW)	1659	2519		
		Pearlmillet (AHB-1666) + pigeonpea (BSMR-853) (3:3) (sowing) on 28th SMW	2086	2358		
		Sole pigeonpea (BSMR-853) (sowing on 28th SMW)	2913			
		Sorghum (CSH-9) + Pigeonpea (BSMR-853) (3:3) (Sowing on 28th SMW)	3456	2241		
		Cotton (PHH-316) + soybean (MAUS-71) (1:1) (Sowing on 28th SMW)	1357	1270		

3.4.3 Rainwater management

At Akola, the studies on drought management indicated that application of potash @ 20 kg/ha gave 9% additional grain yield of sorghum (6226 kg/ha) compared to no application of potash (5708kg/ha). Among cultural practices, combination of crop residue mulch, thinning and furrow opening enhanced the productivity by 628, 206, 1199 kg/ha compared to furrow opening (5807 kg/ha), crop residue mulch (6231 kg/ha) and thinning (5390 kg/ha) respectively. The pooled results over years (2000-06) indicated that opening of furrows after every two rows, spreading of crop residue mulch and thinning 20 percent of recommended plant population showed promising results. In respect of potash application, the productivity of sorghum was higher by 425 kg/ha over no potash application (3805 kg/ha). Hence, it is recommended that 20 kg K_2O/ha at the time of sowing furrow opening after every two rows, 20% of recommended plant population, thinning and crop residue mulching between 30-40 days after sowing would get stability of production in sorghum. In cotton, application of potash @ 20 kg/ha gave higher productivity of stalk yield by 355 kg/ha over no potash application (3858 kg/ha). In respect of cultural practices, crop residue mulch gave highest cotton seed yield (2248 kg/ha), followed by furrow opening (2145 kg/ha). The pooled results (2000-06) indicated that seed cotton yield difference between potash and no potash was at par in respect of seed cotton yield. Among cultural practices, opening of furrow after every two rows between 30-40 days after sowing recorded significantly higher seed cotton yield (1067 kg/ha), closely followed by crop residue mulch (944 kg/ha). As a part of contingency planning in soybean, application of potash 20 kg/ha gave higher seed yield of soybean (330 kg/ha) over no potash application (2304 kg/ha). Based upon three years' results (2004-06), in two out of 3 years, application of potash @ 20 kg/ha at the time of sowing recorded significantly higher grain yield than no potash application. Adoption of all three cultural practices together opening of furrows after every two rows, thinning of 20% recommended plant population and crop residue mulching between 30-40 days after sowing recorded over all significantly higher grain yield in sorghum.

At Parbhani, *in situ* rain water conservation techniques (opening of furrow after every 4 rows) had beneficial effect on productivity (1185 kg/ha of soybean and 895 kg/ha of pigeonpea kg/ha) and soybean grain equivalent (2229 kg/ha) and monitory returns (Rs. 24444 /ha) of soybean + pigeonpea intercropping system. Highest productivity (3771 kg/ha), monitory returns (Rs. 45926/ha) and soybean grain equivalent (4374 kg/ha) were

recorded in opening of furrow with recommended dose of fertilizer. As a part of stress management in different cropping systems, the productivity of sorghum + pigeonpea was significantly higher (4465 kg/ha) than that of soybean + pigeonpea (2583 kg/ha). There is no significant difference in productivity of cropping systems due to stress management techniques, such as, Kaoline spray and reducing 1/3 plant population due to non-occurrence of dry spell exceeding 21 days during growth period of intercrop of soybean and sorghum. However, higher productivity (3685 kg/ha) was noticed with opening of furrows after every 4 rows, followed by Kaoline spray (3535 kg/ha).

At Kovilpatti, use of coir pith @ 5 t/ha recorded in cotton recorded highest seed yield (520 kg/ha) followed by gypsum @ 5 t/ha (491 kg/ha) and vermi-compost @ 5 t/ha (473 kg/ha). The yield increase in coir pith, gypsum and vermi-compost were 38.7, 30.8, and 26 percent respectively compared to control (375 kg/ha). In maize, highest grain was realized with coir pith (1444 kg/ha), followed by gypsum (1425 kg/ha). Application of coir pith to cotton and maize crops helped in reducing the runoff by 59 and 61 percent respectively and increasing the soil moisture content thereby increased crop yields with a tune of 39 percent in cotton and 32 percent in maize **(Table.43).**

Table.43. Influence of rain water management practices on productivity of different crops in cotton based production system

Center	Crop/ system	Treatments	Yield (kg/ha) 2005-06		Mean over years	
Akola	Cotton+ soybean (5)– sorghum (4)	Crop residue	2248	2490	658	839
		Furrow opening	2145	2567	618	887
		Soil mulch with application of 20 kg K/ha	2109	2634	622	912
		Soil mulch without application of K	1826	2304	543	819
Kovilpatti	Cotton and maize	Control	375	1094		
		Coir pith @ 5 t/ha	520	1444		
		Gypsum @ 5 t/ha	491	1425		
		Vermi-compost	473	1269		
Parbhani	Soybean + pigeonpea	Absolute control	1104	750		
		Opening furrow after every 4 rows	1181	895		
		Opening furrow after every 4 rows + RDF	1882	1889		
		Opening furrow after every 4 rows + 50% RDF + 2.5 t/ha FYM	1833	1537		
		Flat bed with RDF	1410	1420		
Parbhani (Auran gabad)	Soybean + pigeonpea	Absolute control	732	829		
		Opening of furrow every after 4 rows + RDF	1429	1605		
		Opening of furrow every after 4 rows + 50% RDF + 2.5 t/ha FYM	1129	1261		
		Opening of furrow every after 4 rows + 50% RDF + 105 t/ha Vemi-compost	1102	1190		
Parbhani	Sorghum + pigeonpea (4:2)	Control	2486	931		
		Opening furrow every after 4 rows	2697	989		
		Kaoline spray (6%during dry spell exceeding 21 days)	2589	946		
		Reducing 1/3 plant population	2511	947		

(Figures in Parentheses indicate no. of years of the experiments conducted)

Furrow opening and mulching in Cotton at Akola

3.4.4 Integrated nutrient management

At Akola, in cotton+greengram sequence system, the highest cotton seed yield was recorded with 25 kg N + 25 kg $P_2$05/ha through inorganic fertilizer and 25 kg organic N through FYM (1241 kg/ha), followed by 25 kg N through *Leucaena* (1185 kg/ha) during 2005-06), ie. 19th year of experimentation, while the highest green gram yield was recorded by 25 kg N + 25 kg P/ha through inorganic fertilizer and 25 kg organic N through FYM (3935 kg/ha). Application of organic manure alone and in combination with organic fertilizer improved the organic carbon, available nitrogen, P and K content of the soil as compared to the initial status.

In Permanent management trials (PMT), application of 15 kg N/ha through compost and 20 kg N/ha through inorganic fertilizer (4100 kg/ha) and 15 kg N through compost and 10 kg N through green leaf manure (4040 kg/ha) were at par in realizing grain yield in sole sorghum. The sorghum in strip cropping recorded highest grain yield of 2392 kg/ha with 100 percent recommended N and application 15 kg N/ha through compost and 20 kg N through inorganic fertilizers, 15 kg N through compost and 10 kg N through inorganic fertilizers were at par in respect of grain yield. 15 kg N through compost and 25 kg N/ha through inorganic fertilizers recorded highest seed yield in sole pigeonpea (1866 kg/ha) and pigeonpea grown in strips (863 kg/ha).

The influence of organic sources on productivity of different crops at Parbhani indicated that application of 100 percent RDF gave the highest productivity of cotton (1158 kg/ha) and blackgram (399 kg/ha) which gave highest cotton seed equivalent yield (1601 kg/ha) and also highest monetary returns (Rs.28826/ha).

Among different organic sources, highest productivity was noticed with discarded grains 3 t/ha gave seed cotton equivalent yield (1294 kg/ha) with monetary returns of Rs. 23302/ha. This combination was closely followed by FYM and glyricidia.

At Kovilpatti, there was no marked difference in yield of sorghum grain due to varied nutrient management practices. However, 40 kg N/ha as urea and 20 kg P/ha and 20 kg K/ha gave highest grain yield of sorghum (2850 kg/ha) and N use efficiency (4.8 kg/kg) compared to the recommended dose of fertilizer of 40 kg N + 20 kg P/ha (2833 kg/ha). In respect of blackgram, application of recommended N of 40 kg/ha as organics (FYM alone) had a beneficial effect to obtain the highest yield (367 kg/ha of cotton and 123 kg/ha of blackgram), profit, BC ratio, N use efficiency and moisture use efficiency in cotton (KC-2) intercropped with blackgram (CO-5). Permanent manurial experiment on millets (sorghum) indicated that 20 kg N/ha as urea + 20 kg N/ha as FYM + 10 kg P/ha as SSP recorded higher sorghum grain and straw yield of 1220 and 3245 kg/ha, followed by application of 40 kg/ha as urea + 20 kg P/ha as SSP + 25 kg Zn SO_4/ha with a yield of 1185 kg/ha.

The long-term manurial experiment on cotton+sorghum intercropping indicated that application of urea 20 kg N/ha + FYM at 20 kg N/ha + SSP at 20 kg P/ha recorded higher grain yield of 2158 and 112 kg/ha in sorghum and cowpea crops respectively with a BC ratio of 2.34. 40 kg N as urea + 20 kg P/ha as SSP recorded the grain yield of 2113 kg/ha of sorghum and 110 kg/ha of cowpea. In sorghum and cowpea intercropping system, application of 50 kg N/ha as compost and 20 kg N/ha as inorganic fertilizer recorded highest values of yield attributes of sorghum in sole and intercropping system.

Cotton grown with organic inputs recorded higher seed cotton yield by 2.4 q/ha and the increased gross monetary returns was Rs. 4403/ha. However, in respect of net monetary returns, inorganic cotton recorded higher net monetary returns of Rs. 5928/ha ie. 28.3% **(Tables. 44, 45 and 46).**

Table.44. Influence of integrated nutrient management practices on productivity of different crops

Center	Crop/system	Treatments	Yield (kg/ha)		Mean over years		SYI	
			1	2	1	2	1	2
Akola	Cotton + greengram (1:1) (10)	Control	635	179	356	306	0.05	0.30
		25kg N + 25 kg P2O5 + 25 kg FYM/ha	1241	393	600	455	0.25	0.52
		25 kg N + 25 kg P2O5 + 25 kg LL/ha	1185	332	532	398	0.20	0.44
		50 kg N + 25 kg P_2O_5/ha	1071	281	514	426	0.18	0.48
Kovilpatti	Cotton + blackgram (5)	Absolute control	126	50	192	111	0.01	0.10
		FYM @ 40 kg N/ha	367	123	402	152	0.02	0.21
		FYM @ 20 kg N/ha + urea @ 20 kg N/ha	288	120	530	212	0.11	0.36
		Green leaf manure @ 40 kg N/ha	221	97	400	183	0.02	0.28
Kovilpatti	Sorghum + cowpea (4)	Control	1785	71	1512	52	0.24	0.01
		20 kg N (urea) + 20 kg N (FYM) + 20 kg P (SSP)/ha	2158	112	2658	72	0.59	0.02
		40 kg N (urea) + 20 kg P (SSP)/ha	2113	100	2098	83	0.42	0.04
		40 kg N (FYM) + 20 kg P (SSP)/ha	2052	110	2314	88	0.49	0.05
Kovilpatti	Sorghum + cowpea (6 & 5)	Control	758	71	1345	557	0.31	0.01
		15 kg N (compost) + 20 kg N (inorganic)	2395	148	2235	845	0.59	0.01
		15 kg N (greenleaf) + 20 kg N (inorganic)	2313	150	2128	758	0.56	0.01
		15 kg N (compost) + 10 kg N (inorganic)	2160	143	2103	659	0.55	0.01

Center	Crop/system	Treatments	Yield (kg/ha)		Mean over years		SYI	
			1	2	1	2	1	2
Akola	Sorghum + pigeonpea (strip) (6 & 2)	Control	916	519	908	431	0.01	
		15 kg N (compost) + 25 kg N (inorganic)	2460	863	1491	812	0.22	
		100% RDN	2392	724	1537	568	0.24	
		15 kg N (greenleaf) + 10 kg N (inorganic)	2326	636	1191	531	0.11	
Parbhani	Cotton + blackgram	Control	397	102				
		100% RDF	1158	399				
		FYM @ 2.5 t/ha + 50% RDF	952	339				
		Discarded grains @ 3 t/ha	931	326				

(Figures in Parentheses indicate no. of years of the experiments conducted)

Table. 45. Influence of integrated nutrient management practices on productivity of different crops in cotton based production system

Center	Crop/system	Treatments	Yield (kg/ha)	Mean over years	SYI
Akola	Sorghum sole (7)	Control	2439	1346	0.01
		15 kg N (compost) + 25 kg N (inorganic)	4100	1948	0.15
		15 kg N (compost) + 10 kg N (greenleaf)	4040	1857	0.13
		100% RDN	3895	2100	0.18
Kovilpatti	Sorghum (4)	Control	1019	871	0.10
		50% N (FYM) + 50% N (urea) + 10 kg P/ha	1220	1474	0.36
		100 % N (urea) + 20 kg P /ha + 25 kg ZnSO4/ha	1185	1293	0.28
		100% RDF (40:20:0 kg NPK/ha)	1164	1197	0.24
Kovilpatti	Sorghum (sole) (6)	Control	720	1059	0.26
		15 kg N (compost) + 20 kg N (inorganic)	2428	2087	0.64
		15 kg N (greenleaf) + 20 kg N (inorganic)	2345	1947	0.59
		15 kg N (compost) + 10 kg N (inorganic)	2193	1892	0.57
Akola	Pigeonpea (sole) (2)	Control	814	543	
		100% RDN	1681		
		15 kg N (compost) + 25 kg N (inorganic)	1866	1271	
		15 kg N (compost) + 10 kg N (greenleaf)	1779	1077	
		15 kg N (compost) + 10 kg N (inorganic)	1759	1120	
Kovilpatti	Sorghum (2) (sole)	Control	2658	1950	
		40 kg N (Urea) + 20 kg P_2O_5 + 20 kg K_2O/ha	2850		
		10 kg N (GLM) + 10 kg N (EFYM)/ha	2800	1790	
		20 kg N/ha (EFYM)	2767	2301	
		10 kg N as OFR + 10 kg N (EFYM) /ha	2667	1996	
		40 kg N (urea) + 20 kg P_2O_5/ha	2833		
	Cowpea (sole) (2)	Control	358	367	
		15 kg N (compost) + 20 kg N (inorganic)	763	684	
		15 kg N (greenleaf) + 20 kg N (inorganic)	748	671	
		15 kg N (greenleaf) + 20 kg N (inorganic)	735	659	

OFR : On-farm residue EFYM : Enriched FYM

Organic farming

At Parbhani, soybean + pigoenpea produced highest mean productivity followed by cotton + blackgram and greengram-*rabi* sorghum cropping systems. Soybean + pigeonpea intercropping recorded highest monetory returns (Rs. 35291/ ha). Application of glyricidia @ 3 t/ha and FYM @ 5 t/ha recorded 71 and 72% mean productivity compared to the recommended dose of fertilizers. The increasing productivity with the corresponding sources of organic farming was 39 and 41 percent over absolute control respectively. Integration of organic and inorganic sources showed promising results over control. Highest productivity of 3849 kg/ha was recorded in sorghum and pigeonpea intercropping with full dose of recommended fertilizers. Similarly, combination of inorganic and organic treatments was found next best to that of fully recommended dose fertilizers.

Table. 46. Integrated nutrient management in legume based cropping systems under rainfed condition – Parbhani

Cropping system	Organic farming		Inorganic farming	Integration of org. + onorg.		Control		Mean
	FYM	GLY	RDF	FYM	GLY	With rotation	Without	
Sorghum + pigeonpea								
Sorghum	1694	1622	2399	1972	2022	999	596	1615
Pigeonpea	877	903	1450	1037	1031	629	509	919
Soybean + pigeonpea								
Soybean	1279	1301	1731	1716	1620	898	851	1342
Pigeonpea	1277	1185	1555	1314	1244	1009	907	1213
Cotton + blackgram								
Cotton	1179	1094	1520	1342	1314	796	601	1121
Blackgram	268	309	453	370	351	235	209	314
Greengram - R. Sorghum								
Greengram	313	281	369	333	291	237	153	282
Rabi Sorghum	1318	1305	1769	1518	1499	1157	763	1333
Mean grain eqt.	4441	4266	5812	5068	4952	3112	2629	4326

GLY indicates glyricidia

Soybean + pigeonpea (4:2) under organic farming with glyricidia 3 t/ha at Parbhani

3.4.5 Tillage and nutrient management

At Akola, the grain yield differences in sorghum with varied tillage as influenced by the tillage treatments (ploughing + interculture operation + hand weeding conventional tillage + low tillage + hand weeding-low tillage + herbicides) were found to be non-significant. However, low tillage + herbicide + recommended dose of nutrients with 50 percent organic (FYM/ glyricida) + 50% through inorganic gave highest grain yield of sorghum (5110 kg/ha).

At Parbhani, cotton + soybean intercropping system, conventional tillage recorded higher grain yield of soybean (1047 kg/ha), cotton (1051 kg/ha), monetory returns (Rs. 31087/ha) with seed cotton equivalent yield (1636 kg/ha) compared to reduced tillage with interculture (1660 kg/ha) and reduced the tillage with herbicide (1288 kg/ha). Reduced tillage with interculture recorded higher productivity than reduced tillage with herbicides. Among nutrient sources, productivity was significantly higher in RDF (2103 kg/ha) than that of FYM @ 5 t/ha, vermi-compost @ 3 t/ha and sole organic sources. The INM with FYM and vermi-compost recorded significantly higher productivity in soybean-cotton system over respective sole source combinations. Among tillage methods, conventional tillage produced minimum runoff (275.1 mm) whereas reduced tillage with herbicide produced maximum runoff (297.7 mm). Organic sources produced minimum runoff (282.86) as against maximum runoff with inorganic sources. (292.13). The soil loss varied from minimum of 8.77 t/ha in conventional tillage as against 11.03 t/ha in reduced tillage with herbicides. Minimum bulk density and maximum infiltration were observed in conventional tillage. In respect of energy, cotton + soybean cultivation required 10971 mj/ha followed by reduced tillage for interculture (9042 MJ/ha). Among nutrient sources, inorganic sources required maximum energy (12196 MJ/ha) as against minimum of 6710 MJ/ha in respect of organic sources.

At Kovilpatti, conventional tillage (1 disc ploughing + 2 harrowings) recorded a highest grain yield of pearlmillet 1071 kg/ha), followed by low tillage treatment (1 harrowing) along

Cotton + Soybean (1:1) at Parbhani

with application of weedicide (949 kg/ha). Among the nutrient management systems, 50% of organic manure and 50% of inorganic through urea gave a highest grain yield of pearlmillet (1000 kg/ha), followed by 100% through inorganic urea (942 kg/ha). Conventional tillage along with combined application of 50% RDN as inorganic fertilizer and 50% as organics resulted with highest grain yield of pearlmillet.

At Parbhani, highest sorghum grain equivalent yield was recorded in sorghum with minimum tillage (3475 kg/ha), monetary returns (Rs.17373/ha), followed by mechanical tillage for sorghum with a productivity of 3287 kg/ha) with monetory returns of Rs.16434/ha. In soybean, mechanical tillage recorded the highest productivity, monetory returns and also sorghum grain equivalent followed by conventional tillage **(Tables. 47 and 48)**.

Table. 47. Influence of tillage and nutrient management on productivity in cotton + soybean system at Parbhani

Treatments	Yield (kg/ha)	
	1	2
Conventional tillage	1050	1047
Low tillage + interculture	789	871
Low tillage + herbicide	605	683

Cotton + soybean (1:1) under conventional tillage + vermicompost 3 t/ha, Parbhani

3.4.6 Alternate land use system and parming systems

At Akola, ber plantation recorded highest gross monetory returns (Rs. 7120/ha) with additional yield of 193 kg/ha of greengram as intercrop giving additional income of Rs. 5365/ ha during 2005-06.

The integrated farming system for sustainable in dryland vertisols at Kovilpatti (viz., conventional cropping systems (cotton+blackgram, sole greengram and sole sorghum), crop+goat +poultry with areable cropping systems, crop+goat+poultry+diary, crop+goat+poultry with areable cropping systems, crop + goat+poultry+sheep) was conducted during 2005-06.

Salient findings of the study are –

- Two batches of broiler chicks @ 80 nos/batch) @ 20 nos./ batch/model were maintained, which were sold at the end of 7-8 weeks. A sum of Rs. 1584, Rs. 1527, Rs. 1545 and Rs. 1554 has been realized for each model by sale of 2 batches of broiler chicks.
- From the milch animals, the milk yield was 1743 litres and 1759 litres from which a sum of Rs 20916/- and Rs. 21222/ - have been obtained in model B and model D.
- By sale of goats and sheep (including the value of available stock) a sum of Rs. 17980/-, Rs. 17980/-, Rs. 33119/- and Rs. 35356/- have been added for each model respectively.
- The fodder cholam, desmatnthus, subabool and agathi were cut and fed to the cattle. The neem and vagai leaves grown in the boundary of the field were fed to the goats and sheep during the lean season.
- From the crop components, a sum of Rs. 5885/-, Rs. 5720/ -, Rs. 5910/- and Rs. 5955/- have been received as gross income for each integrated farming system model where as sum of Rs. 5860 has been obtained as gross income from the conventional crop cultivation.

Table. 48. Influence of tillage and nutrient management on productivity of different crops in cotton based production system

Center	Crop	Treatments	Yield (kg/ha)	Mean over years
Akola	Sorghum (3)	Low tillage + herbicide + 50% inorganic + 50% organic (FYM/glyricidia)	5110	
		Low tillage + hand weeding + 50% inorganic + 50% organic (FYM/glyricidia)	5053	
		Conventional tillage + interculture + 50% inorganic + 50-% organic (FYM/glyricidia)	4857	
Kovilpatti	Pearlmillet (2)	Conventional tillage + interculture	1071	1167
		Low tillage + Interculture + weedicide	949	955
		Low tillage + interculture	851	912
Parbhani	Sorghum	Minimum tillage	3475	
		Mechanical tillage	3287	
		Conventional tillage	3259	
	Soybean	Mechanical tillage	2496	
		Conventional tillage	2164	
		Minimum tillage	1989	

- Among different integrated farming system models, model D, having Crop + Goat + Poultry + Sheep + Dairy produced higher gross income of Rs. 5955/ac.

In another study, agri-horti system, there was no significant difference in growth of seedlings of sapota during different field crops grown in the inter spaces. Among intercrops, greengram gave highest net income Rs. 6207/ha, followed by cotton (Rs. 3407/ha) with BC ratio of 1.40.

3.5. Nutritious Cereals Based Production System

3.5.1 Sorghum based production system

3.5.1.1 Crops and varieties

At Bijapur, sunflower CV MLHT-12 of sunflower recorded maximum yield (2423 kg/ha), followed by MLHT-11 (2387 kg/ha) and MLHT-9 (2128 kg/ha) as against local check NSP-92-1 (E) (1135 kg/ha). In Spanish bunch groundnut, improved genotypes of DH-403 (1808 kg/ha) recorded maximum pod yield, followed by DTG-3 (1374 kg/ha) and DH-203 (1361 kg/ha) during *kharif* season. In spreading groundnut genotypes, GPM-425 (700 kg/ha), JSP-33 (688 kg/ha) and JSP-35 (617 kg/ha) were superior. Among millets, foxtailmillet genotype FMLT-11 (2109 kg/ha), FMLT-7 (2072 kg/ha), FMLT-4 (2035 kg/ha) and FMLT-10 (2035 kg/ha) recorded good performance under rainfed environment. The barnyard millet genotype BMLT-10 recorded maximum yield (2491 kg/ha) and BMLT-9 (1875 kg/ha) under vertisols in *kharif* season. Little millet genotypes of LMLT-5 (651 kg/ha), LMLT-1 (498 kg/ha) and LMLT-4 (360 kg/ha) recorded stable yields in rainfed vertisols during 2005. Improved cultivars of cowpea (DCS-5-1-47 and DCS-5-2-2), sesame (DSS-9, DSS-8 and E-8(C), linseed (RL-0117, RL-040710 and RL-040406), horsegram (GPM-6, PHG-20 and DFH-1) and Mulberry (S-1635) gave 40-60% enhanced yields as against corresponding local checks in rainfed vertisols.

In Solapur, the improved cultivars of castor viz., CK-05-AHT-41, CK-05-AHT-43, horsegram viz., HG-15 and HG-17, Mothbean viz.,MB-3, MB-5 and MB-2 and viz., clusterbean G-28, G-16 recorded stable and higher yield with an age of 30% increment in the yield over respective locals in rainfed vertisols **(Tables. 49 and 50).**

Horsegram cv GPM-6 at Bijapur

Table.49. Influence of improved varieties on productivity in sorghum based production system

Center	Crop	Varieties	Yield (kg/ha)	
			2005-06	Mean over years
Bijapur	Horsegram (8)	PHG-20	622	563
		GPM-73	567	634
		GPM-6	636	790
		KBHG-1	548	612
		Bijapur local	444	575
		PHG-62	488	610
		DFH-1	592	573
Solapur	Horsegram	HG-1	1389	1389
		HG-2	976	976
		HG-3	1030	1030
		Man	725	725
		Seena	1339	1339
Bijapur	Mulberry (3)	RFS-135	16780	16780
		S-1635	25310	25310
		DD	22470	22470
		Cucko Pilla	17500	17500
		Tr-10	22150	22150
Bijapur	Groundnut (spreading) (2)	GPM 425	700	702
		JSP-33	688	909
		JSP-35	617	834
		JSP-37	614	761
Bijapur	Groundnut (bunch) (2)	Dh – 101	953	1164
		Dh – 103	1397	1172
		Dh – 203	1361	1514
		DTG - 1	1326	1417
		DTG - 3	1374	1472

Center	Crop	Varieties	Yield (kg/ha)	
			2005-06	Mean over years
		Dh - 4- 3	1343	1575
		JL -24 (c)	1352	1385
Bijapur	Foxtail millet (2)	FMLT-2	1850	1758
		FMLT-3	1813	1972
		FMLT-4	2035	2072
		FMLT-7	2072	2285
		FMLT-10	2035	2155
		FMLT-11	2109	1648
		FMLT-12	1813	1767
	Barnyard millet (2)	BMLT-1	1692	1020
		BMLT-4	1825	1586
		BMLT-6	1855	1490
		BMLT-9	1875	1818
		BMLT-10	2491	1867
Bijapur	Cowpea (2)	DCS -5-1-47	705	833
		DCS - 5-2-2	629	735
		DCS -5-3-18	564	882
		DCS - 5-3-20	552	766
		DCS-6 ©	515	783
Solapur	Mothbean	MB-1	278	282
		MB-2	297	253
		MB-3	328	297
		MB-5	320	301

(Figures in parentheses indicate no. of years of the experiments conducted)

Table.50. Influence of improved varieties on productivity in Sorghum based production system

Center	Crop	Varieties	Yield (kg/ha)
Bijapur	Littlemillet (1)	LMLT-1	498
		LMLT-2	345
		LMLT-4	360
		LMLT-5	**651**
Bijapur	Cotton	RAHS - 14	377
		DB 3-12	430
		Jayadhar	731
Solapur	Castor	CK -05-AHT-39 (Aruna ©)	1047
		CK -05-AHT-41	1607
		CK -05-AHT-42	1268
		CK -05-AHT-43	1268
		CK -05-AHT-45	1219
Solapur	Clusterbean	G-2	417
		G-5	509
		G-6	372
		G-7	472
		G-8	490
	Linseed	050102	373
		050105	362
		050106	388
		050109	417
		050110	333
	Castor (IHT)	CK-05-IHT-24	1744
		CK-05-IHT-34	1698
		CK-05-IHT-26	1651
		CK-05-IHT-32	880

Center	Crop	Varieties	Yield (kg/ha)
	Horsegram (IVT)	HG-15	1312
		HG-17	1208
		HG-27	1106
		HG-18	745
	Clusterbean (IVT)	G-28	554
		G-16	545
		G-15	509
		Local check	236
Solapur	Sorghum (AV/HT)	503,553,580	2710
		507,551,574	2574
		513,532,571	2559
		514,554,578	1563
	Sorghum (AV/HT)	405,436,483	2966
		425,454,489	2740
		403,442,472	2680
		407,433,474	783

(Figures in parentheses indicate no. of years of the experiments conducted)

3.5.1.2 Cropping systems

At Jhansi, Bajra (fodder)- barley + mustard (gram) crop sequence registered highest green fodder yield (35.2 t/ha), dry matter yield (8.01/ha) and crude protein (630 kg/ha followed by sorghum + cowpea (F)-Chickpea + Linseed (G) in respect of green fodder yield (28.44 t/ha) and dry matter yield (6.1 t/ha) and crude protein yield (700 kg/ha) in rainfed vertisols during erratic distribution years.

In pearlmillet + pigeonpea, highest intercropped pearlmillet yield was recorded with pigeonpea + pearlmillet (2:1) (2745 kg/ha) at Solapur, while pigeonpea in intercropping system recorded highest grain yield in pearl millet + pigeonpea (3:6) (709/ha). Intercropping of pearl millet +pigeonpea (2:1) registered highest pearlmillet grain equivalent yield (5382 kg/ha) with 58 % additional yield advantage compared to sole crops of pigeonpea and pearl millet with highest net returns (Rs. 20887/ha) and B:C ratio (2.83). The yield of sunflower-pigeonpea ranged between 834-1460 as against sole crop (1669 kg/ha), while the pigeonpea intercropping system was ranged from 591-780 kg/ha as against sole crop (1010 kg/ha). Sunflower+pigeonpea (6:3) recorded highest gross returns (Rs. 14340/ha).

At Bijapur, castor (60 x 15 cm) + sunflower (60 x 20 cm) (2:4) recorded highest gross returns (19781 kg/ha) and net returns (11202 kg/ha), followed by castor + sunflower (1:1) system which gave a gross income of Rs. 18695/ha and net returns of Rs. 11121/- per ha and on average recorded additional net income of Rs. 5688 and 7362/- per ha compared to the sole crops of castor and cotton respectively. In another study, chilli + onion (2:4) recorded highest net returns Rs. 71232/ha, followed by chilli + onion (2:8) (Rs. 61184/ ha). Among nutrient management practices, poultry manure (1 t/ha) + residue incorporation showed 9 percent higher returns compared to farmers' practices (Rs. 30937/ha). The crop rotation studies in different cropping systems indicated that chilli + cotton (1:1) recorded highest net income (6288/ha), followed by sequence cropping of sunflower (135 cm) during *kharif* and chickpea during *rabi* (Rs. 5170/ha). The net income of first cycle of crop rotation was highest with pigeonpea + greengram (2:4) rotated with chilli + cotton (1:1), followed by sequence cropping of sunflower-chickpea system **(Tables. 51, 52 and 53).**

Table.51. Influence of cropping systems on productivity at Solapur

Center	Crop/ System	Treatment	Yield (kg/ha) 1	Yield (kg/ha) 2	Gross Returns (Rs/ha)	LER
Solapur	Pearlmillet + pigeonpea	Pearlmillet + pigeonpea (1:1)	2501	526	4433*	1.32**
		Pearlmillet + pigeonpea (2:1)	2745	711	5382	1.58
	*Gross returns	Pearlmillet + Pigeonpea (2:2)	2549	403	4222	1.22
	** LER	Pearlmillet + pigeonpea (3:3)	2551	448	4375	1.26
		Pearlmillet + pigeonpea (6:3)	2682	581	4946	1.44
		Pearlmillet + pigeonpea (3:6)	1960	709	4572	1.34
		Sole pearlmillet	3112			
		Sole pigeonpea				

(Figures in parentheses indicate no. of years of the experiments conducted) LER indicate Land Equivalent ratio

Table.52. Influence of cropping systems on productivity at Bijapur

Center	Crop	Treatments	Net Returns (Rs./ha)	
Bijapur	Intercropping	**Nutrient management**		
		Farmers' practice (FYM @ 5 t/ha)	30937	18935
		Poultry manure (1t/ha) + residue incorporation	33800	26840
		Cropping system		
		FP (Chili (60cm) in *Kharif*, cotton in intrarow of chilli	15240	5330
		Chilli + cotton (1:1) (120 x10 cms) chilli in *kharif* later on cotton at 60 cm	31990	18943
		Chilli + cotton (2:2) at 45-135 cms paired row	36113	21824
		Chilli + onion (2:4)	71232	57909
		Chilli + onion (2:8)	61184	46332
		Cotton + onion (2:4), cotton will be sown later	4704	3816
		Cotton + onion (2:8) cotton will be sown later	6117	6053

Pearlmilet + pigeonpea (3:6) at Solapur

Pigeonpea + sunflower (3:6) at Solapur

Table.53. Influence of cropping systems on productivity at Solapur

Center	Crop	Treatments	Main crop	Intercrop	GEY	LER
Solapur	Sunflower + pigeonpea	Sole sunflower	463	—	—	
		Sole pigeonpea	653	—	—	
		Sunflower + pigeonpea (6:3)	263	511	14340	—
		Sunflower + pigeonpea (2:1)	207	548	13918	—
		Sunflower + pigeonpea (2:2)	202	517	13452	—

3.5.1.3 Rainwater management

At Jhansi among moisture conservation practices, two harrowings in each season with one deep summer ploughing produced highest green fodder yield (24.44 t/ha), dry matter yield (5.69 t/ha) and crude protein yield (612 kg/ha), followed by two harrowings in each season along with use of weeder-cum-mulcher produced 22.97 t of green fodder, 5.3 t of dry matter yield and 551 kg/ha of crude protein yield. After the completion of second year, there was not much change noticed in soil physio-chemical properties.

In Bijapur, application of 10 cm thick sand mulch produced highest seed yield of sunflower, followed by pebble mulch (1165 kg/ha). Use of sand and pebble mulches recorded 152 and 125 percent increased yield of sunflower compared to the control (518 kg/ha). Cultivation of pearlmillet under set rows with tank silt application (60 cm breadth and 60 cm depth) enhanced the productivity by 200 kg/ha compared to the farmers' practice (1200 kg/ha). In sunflower, tank silt application (60 cm breadth and 60 depth) produced additional grain yield (655 kg/ha) compared to the farmers' practice with 37.72 DAP and 37.72 of urea/ha (950 kg/ha). In drought proofing techniques of *rabi* sorghum, seed hardening with calcium chloride (2%) for 8 hours recorded the highest grain yield (1880) kg/ha, followed by seed soaking with cow urine for 8 hours (824 kg/ha), seed soaking with vermi wash (1656 kg/ha). The pooled data over 2 years revealed that seed soaking with cow urine for 8 hours produced significantly higher grain yield (1808 kg/ha) for *rabi* sorghum compared to other treatments. In chickpea, seed hardening with calcium chloride (2%) for 8 hours registered highest seed yield with 1492 kg/ha. This treatment gave higher additional yield by 649 kg/ha compared to the control (843 kg/ha).

At Solapur, mechanical bund + vertical plastic mulch recorded highest grain fodder yield (1383 kg/ha), followed by mechanical bund alone (1234 kg/ha). Mechanical bund + vertical mulch, mechanical bund contributed the higher

productivity of pearlmillet by 27% and 13% respectively compared to control. In roof water harvesting studies, it was observed that the total quantity of rain water harvested from the roof was 15000 lit during March to October 2005. The water was collected in the tank of 25000-lit capacity constructed underground. This water from the tank was taken out manually and used for growing 20 plants of custard apple and 20 plants of aonla. The stored water when tested found fit for drinking purpose **(Table. 54).**

3.5.1.4 Integrated nutrient management

At Bellary, nutrient supply system through organic and inorganic sources was conducted in three blocks (sorghum-chickpea, chickpea alone and strip cropping of sorghum and chickpea). In cereals block, 15 kg N through green leaf with 20 kg N through inorganic fertilizers significantly recorded higher yield of sorghum by 64 per cent (2200 kg/ha) over control which was at par with 100 percent of recommended dose of nitrogen through inorganic fertilizer (2048 kg/ha) and 50 per cent of RDN through inorganic fertilizer (1968 kg/ha). In pulses block, the influence of residual effects of different nutrient management practices on chickpea indicated that 15 kg N through green leaf + 20 kg N through inorganic fertilizer recorded highest green yield (1399 kg/ha), followed by 100 per cent of RDN through inorganic fertilizer (1302 kg/ha). Use of 15 kg N through green leaf manuring along with the 20 kg N through inorganic fertilizer, 100 per cent of RDN through inorganic fertilizer increased the chickpea yields by 109 and 95 percent respectively. Significantly higher Water Use Efficiency (WUE) of 7.78 and 5.38 kg/ha/mm was observed with 15 kg N through green leaf and 20 kg N through inorganic fertilizer and 15 kg N through green leaf and 10 kg N through inorganic fertilizer respectively. In cereals + pulse strip (sorghum + pigeonpea), use of 15 kg N through green leaf and 20 kg N through inorganic source recorded highest sorghum grain yield (2312 kg/ha) as against the control of 1640 kg/ha. While considering the individual crop yields, highest sorghum grain yield was observed with 15 kg N through green leaf and 20 kg N through inorganic source (637 kg/ha) and chickpea (676 kg/ha).

In Jhansi, in forage based production system, nutrient application 75 percent organic and 25% inorganic recorded 24.9 percent higher yield of subabool, 11.4 percent of perennial grass, 17.8 percent of annuals and 13.5 percent on the basis of total green forage yield of the system. In terms of dry matter, the corresponding values were 34.18, 11.75, 15.75 and 14.61 percent. Among grasses, tri-specific hybrid produced highest grain yield (35.6 percent). In respect of cropping systems, subabool + Trispecific hybrid + sorghum (fodder) + pigeonpea (grain) recorded highest yield of 5 t fresh and 1.6 t green forage/ha. In terms of annul components, cowpea grown in either combination of subabool + TSH or subabool + guinea grass recorded 10.7 t green fodder. In a field trial on food-fodder

Table. 54. Influence of rain water management of practices on productivity of different crops in sorghum based production system

Center	Crop	Treatments	Yield (kg/ha)	Mean yield over the years
Bijapur	*Rabi* sorghum	Untreated	1277	1029
		Water soaking for 8 hrs	1389	1249
		Seed hardening with $CaCl_2$ (2%) for 8 hrs	1880	1531
		Seed soaking with cow urine for 8 hrs	1824	1808
		Seed soaking with vermiwash for 8 hrs	1656	1297
		Seed treatment with Panchagavya (3%)	1642	1382
		Seed treatment with KH_2PO_4 (2%)	1445	1289
		Boiled and cooled cow urine soaking for 8 hrs	1347	1094
		Boiled and cooled vermiwash soaking for 8 hrs	1319	1068
	Chickpea	Untreated	843	666
		Water soaking for 8 hrs	1132	1195
		Seed hardening with $CaCl_2$ (2%) for 8 hrs	1492	1375
		Seed soaking with cow urine for 8 hrs	1070	1104
		Seed soaking with vermiwash for 8 hrs	1152	1099
		Seed treatment with Panchagavya (3%)	1111	1125
		Seed treatment with KH_2PO_4 (2%)	895	937
Solapur	Pearlmillet	Control	1092	
		Mechanical bunds + vertical plastic mulch	1383	
		Mechanical bund	1234	
Bijapur	Sunflower	Sand mulch of 5 cm depth		
		Sand mulch of 10 cm depth	1290	
		Pebble mulch of 50% SA	1165	
		In situ incorporation of sunhemp	837	

Pearlmilet + pigeonpea (3:6) at Solapur

production system, seasonal changes in soil health in respect of microbial biomass, activity and microbial population were monitored. The results indicated positive influence on the build up microbial biomass and activity in the soil with combined use of FYM-N and Urea-N in 1:1 ratio in all cropping systems. Highest amount of microbial biomass and activity was recorded with subabool + TSH + sorghum + pigeonpea cropping sequence fertilized with the integrated inputs of FYM-N and urea-N in 1:1 ratio in rainy season. Urease activity was higher with sole inorganic nutrients and no herbicide application, whereas alkaline monophosphatase activity was higher with the use of fluchloralin @ 0.75 kg a.i/ha along with 1:1 ratio of organic and inorganic source of nutrients.

At Solapur, the Permanent manurial trial in strips of sole crops (sorghum and chickpea), sorghum + chickpea, the results indicated that 15 kg N/ha through compost and crop residue with 20 kg N/ha of urea recorded sole sorghum grain yield (1247 kg/ha). This combination was at par with 50 kg N/ha through urea (1207 kg/ha). In sole chickpea, 15 kg N/ha through *Leucaena* and 20 kg N with urea recorded highest grain yield (860 kg/ha) followed by 15 kg N/ha through compost, crop residue and 20 or 10 kg N through urea (845-855 kg/ha). In strip cropping, use of 15 kg N/ha through compost, crop residue and 20 kg N through urea/ha recorded highest sorghum yield (658 kg/ha) and also chickpea yield (562 kg/ha). The pooled results over years indicated that organic carbon content of the soil at sowing was in the range of 0.48 to 0.64 %, and it was increased at 60 DAS (0.62 – 0.69) and again it was decreased at harvest stage (0.56 – 0.58 %). The residual effect of different treatments under sole chickpea showed that the organic carbon content of soil at sowing in the range of 0.41 to 0.57% and 60 DAS it was increased in all treatments (0.52 to 0.64%), however, it was decreased at harvest stage (0.46 to 0.60%). Application of N through organic sources improved the hydraulic conductivity and infiltration rate of the soil at the 8th year of the experimentation.

The pooled results of 8 years revealed that there was no significant difference in sorghum grain equivalent yield with sorghum+chickpea strip cropping system due to application of 50 kg N through urea and 15 kg N through compost and crop residue along with 20 kg N through urea as well as 15 kg N through *Leaucaena and* 20 kg N through urea. Thus the study clearly indicated that application of 15 kg N through compost and crop residue + 20 kg N through urea to only *rabi* sorghum in sorghum+chickpea strip cropping (4:6) in inceptisols is recommended for achieving higher yields, better soil health, and sustainability under dryland conditions of scarcity zone of Maharshtra.

At Bijapur, in cereal (Sorghum)-legume (chickpea), highest chickpea yield was recorded with application of 15 kg N through compost/sunhemp and 20 kg N through fertilizer, while in *rabi* sorghum 15 kg N through compost/sunhemp + 20 kg N through fertilizer recorded the highest grain yield in rainfed vertisols. In pearlmillet + pigeonpea cropping system (2:1), 50 percent organics and 50 percent through fertilizers recorded the highest grain yield of pearlmillet, while grain yields of pigeonpea did not differ significantly. The organic farming studies in sunflower-*rabi* sorghum system revealed that the grain yield of sorghum did not differ due to nutrient management practices. However, application of RDF through fertilizers and manures (FYM) was found as a better option for higher productivity, while the grain yield of chickpea did not differ due to nutrient management practices. However, comparatively higher yields were obtained with integrated supply system of organics and inorganics.

At Solapur, the highest grain yield of *rabi* sorghum was obtained with 25 kg N/ha through crop residue and also with 25 kg N/ha through *Leucanea* loppings (1384 kg/ha). In *rabi* sorghum, highest grain yield (1405 kg/ha) was recorded with cowpea manuring. Among various green manuring crops, there is no significant variation in yield of *rabi* sorghum during 2005-06.

At Solapur, in sole crop of *rabi* sorghum sown at 45 x 25 cm spacing recorded the highest grain yield (1325 kg/ha), net returns (5969 kg/ha) and BC ratio of 1.67. In respect of fertilizer trials, use of 75 kg N + 37.5 kg P/ha recorded the highest grain yield (1277 kg/ha) and fodder yield (4047 kg/ha), followed by 60 kg N, 30 kg P/ha, which yielded 1155 kg/ha and 3825 kg fodder. Thus the results over the years (1999-2006) conclusively showed that the sowing of *rabi* sorghum hybrid (CSH 15-R) at 45 x 20 cm spacing with 75 kg N + 37.5 P_2O_5/ha through fertilizers in medium deep soils is recommended for achieving higher yield and sustainability under dryland conditions of scarcity zone of Mahrshtra.

At Bijapur, in Permanent manurial trials application of RDF along with 15 kg Zn SO_4 recorded grain yield of safflower (524 kg/ha) as against 50 kg N through FYM and 50 kg through inorganic RDF (549 kg/ha). 50 kg N through sunhemp along with 50% RDF through chemical fertilizer gave at par yield with that of 100% recommended dose of fertilizer (507 kg/ha). The pooled anlysis of data (1991-2005) for *rabi* sorghum and for *rabi* safflower 1992 to 2006 showed that the yield of crops was

significantly higher with application of 50% RDF in conjunction with organics (compost/sunhemp) to meet 50% N. These were comparable with that of application of RDF along with 15 kg Zn SO_4/ha.

At Bijapur, a higher grain of *rabi* sorghum was obtained with application of 15 kg N through compost (1326 kg/ha)/sunhemp (1306 kg/ha) along with 20 kg N through fertilizer. These treatments were comparable with the use of 100% N through fertilizers (1345 kg/ha). In general, the % of soil moisture and water content (cm/60 cm) were higher in organic manure and organic manure + inorganic fertilizers. The pooled results (1999-2006) indicated that application of 15 kg N through sunhemp/compost with 20 kg N through fertilizer gave significantly highest grain yield of *rabi* sorghum in vertisols. Application of 15 kg N through compost along with 10 or 20 kg N through fertilizer recorded highest grain yields in sole chickpea (1150 kg/ha). This combination was on par with that of 15 kg N through compost/sunhemp along with 10 kg N through fertilizer and RDF **(Tables.55, 56 and 57).**

Table.55. Influence of integrated nutrient management of practices on productivity of different crops in sorghum based production system

Center	Crop/ System	Treatment	Yield (kg/ha) 2005-06		Mean yield over the years		SYI	
			1	2	1	2	1	2
Bijapur	Cereal+Legume-	Control	741*	604**	701	464	0.25	0.34
	Rabi sorghum	100% RD N (Inorganic fert)	1404	975	1235	785	0.57	0.62
	(7)	50% RD N (Inorganic fert.)	1072	819	1079	665	0.48	0.51
	Rabi sorghum*	25 kg N (compost)	1238	955	1075	731	0.48	0.57
	Chickpea **	15 kg N (compoast)+10 kg N (Inorganic)	1111	1072	1234	876	0.57	0.69
		15 kg N (compoast)+20 kg N (Inorganic)	1394	1170	1354	872	0.65	0.69
		15 kg N (sunhemp)+10 kg N (Inorganic)	1326	897	1244	790	0.58	0.62
		15 kg N (sunhemp)+20 kg N (Inorganic)	1384	1053	1272	800	0.60	0.63
		15 kg N (compoast)+10 kg N (sunhemp)	1092	936	941	749	0.39	0.58
Bellary	Sorghum +	Control	436	486	535	272	0.01	0.09
	chickpea (5)	100% RDN through IF	594	616	733	326	0.01	0.17
		15 kg N through GL + 20 kg N through urea	637	676	773	370	0.03	0.23
		15 kg N through GL + 10 kg N through urea	599	651	719	353	0.01	0.21

(Figures in parentheses indicate no. of years of the experiments conducted)

Table.56. Influence of integrated nutrient management of practices on productivity of different crops in sorghum based production system

Center	Crop	Treatments	Yield (Kg/ha)	Mean over years	SYI
Bijapur	Safflower (4)	Control	220	133	-0.02
		100 % RDF	507	303	0.29
		50% RDF	388	248	0.19
		RDN alone	448	274	0.23
		RD P2O5 alone	270	180	0.06
		RD N & P2O5	486	291	0.26
		FYM to meet 50% N	405	244	0.18
		FYM to meet 50% N +50%RDF	549	328	0.33
		Sunhemp to meet 50% N	321	252	0.19
		Sunhemp to meet 50% N+50%RDF	515	346	0.37
		RDF + 15 kg ZnSO4/ha	524	320	0.32
Bijapur	*Rabi*	Control	809	954	0.38
	sorghum	100% RD N (Inorganic fert)	1345	1403	0.62
	(7)	50% RD N (Inorganic fert.)	1082	1229	0.53
		25 kg N (compost)	1189	1371	0.60
		15 kg N (compost)+10 kg N (Inorganic)	1082	1338	0.59
		15 kg N (compost)+20 kg N (Inorganic)	1326	1496	0.67
		15 kg N (sunhemp)+10 kg N (Inorganic)	1267	1449	0.65
		15 kg N (sunhemp)+20 kg N (Inorganic)	1306	1517	0.68
		15 kg N (compost)+10 kg N (sunhemp)	1062	1315	0.57
	Legumes –	Control	585	497	0.27
	chickpea (7)	100% RD N (inorganic fert)	955	893	0.54
		50% RD N (inorganic fert.)	809	739	0.43
		25 kg N (compost)	941	827	0.50
		15 kg N (compost)+10 kg N (inorganic)	1053	909	0.55
		15 kg N (compost)+20 kg N (inorganic)	1150	979	0.60

Center	Crop	Treatments	Yield (Kg/ha)	Mean over years	SYI
		15 kg N (sunhemp)+10 kg N (inorganic)	872	811	0.48
		15 kg N (sunhemp)+20 kg N (inorganic)	1023	893	0.54
		15 kg N (compost)+10 kg N (sunhemp)	936	842	0.51
Solapur	Sorghum	**Spacing**			
	Hybrid (5)	45 x 15 cm	981	1486	0.54
		45 x 20 cm	1155	1677	0.62
		45 x 25 cm	1325	1594	0.59
		Fertilizer levels			
		50:25 kg NP/ha	1039	1442	0.52
		60:30 kg NP/ha	1145	1605	0.59
		75:37.5 kg NP/ha	1277	1708	0.64
Bellary	Sorghum +	Control	1340	1176	0.22
	chickpea	100% RDN through IF	2048	1844	0.45
	(4) (Sole	15 kg N through GL + 20 kg N through IF	2200	1846	0.45
	sorghum)	15 kg N through Compost +	1658	1618	0.38
		10 kg N through GL			
Bellary	Sorghum +	Control	669	417	0.03
	chickpea	100% RDN through IF	1302	636	0.19
	(5) (Sole	15 kg N through GL + 20 kg N through urea	1399	705	0.24
	chickpea)	15 kg N through Compost +	1254	624	0.18
		20 kg N through urea			
Solapur	*Rabi*	Control	349	517	0.06
	sorghum	25 kg N/ha (Urea)	577	838	0.27
	(8) (PMT)	50 kg N/ha (Urea)	653	947	0.35
		25 kg N/ha (CR)	721	872	0.30
		25 kg N/ha (FYM)	681	838	0.27
		25 kg N/ha -CR+25 kg N/ha-Urea	848	1095	0.45
		25 kg N/ha -FYM+25 kg N/ha(Urea)	924	986	0.37
		25 kg N/ha –CR + 25 kg N/ha (*Leucaenna)*	1384	1134	0.47
		25 kg N/ha (*Leucaena)*	610	775	0.23
		25 kg N/ha -*Leucaena* +25 kg N/ha (Urea)	739	788	0.24
Solapur	*Rabi*	Control	565	739	0.28
	sorghum	RDF 50 kg N/ha (Urea)	1207	1171	0.51
	(6) (Sole)	25 kg N/ha (Urea)	1058	1033	0.44
		25 kg N/ha* (compost +CR) + 10 kg N (urea)	878	830	0.33
		15 kg N/ha (compost +CR) +10 kg N/ha (Urea)	892	837	0.33
		15 kg N/ha (compost +CR) +20 kg N/ha (Urea)	1247	1076	0.46
		15 kg N/ha (*Leucaena*) + 10 kg N/ha (urea)	886	924	0.38
		15 kg N/ha (*Leucaena*) + 20 kg N/ha (urea)	1190	1138	0.49
		15 kg N/ha - compost +CR+10 kg N/ha	1096	986	0.41
		(Leucaena)			
Solapur	Chickpea	Control	735		0.63
	(6) (sole)	RDF 50 kg N/ha (urea)	781		0.67
		25 kg N/ha (Urea)	745		0.64
		25 kg N/ha (compost +CR) + 10 kg N (urea)	771		0.66
		15 kg N/ha (compost +CR) +10 kg N/ha (Urea)	797		0.69
		15 kg N/ha (compost +CR) +20 kg N/ha (Urea)	855		0.74
		15 kg N/ha *(Leucaena)* + 10 kg N/ha (Urea)	818		0.71
		15 kg N/ha (*Leucaena*) + 20 kg N/ha – Urea	860		0.75
		15 kg N/ha (compost +CR) +10 kg N/ha (*Leucaena*)	840		0.73
Solapur	Strip	Control	446	661	0.22
	chickpea	RDF 50 kg N/ha (Urea)	477	742	0.28
	(6) (strip)	25 kg N/ha (Urea)	470	716	0.26
		25 kg N/ha (compost +CR) + 10 kg N/ha (urea)	529	723	0.26
		15 kg N/ha (compost +CR) +10 kg N/ha (Urea)	540	755	0.28
		15 kg N/ha (compost +CR) + 20 kg N/ha (Urea)	562	769	0.29
		15 kg N/ha (*Leucaena*) + 10 kg N/ha (Urea)	505	742	0.28
		15 kg N/ha (*Leucaena*) + 20 kg N/ha – (Urea)	526	768	0.29
		15 kg N/ha (compost +CR) +10 kg N/ha (*Leucaena*)	489	725	0.26

(Figures in parentheses indicate no. of years of the experiments conducted)

Table. 57. Effect of integrated nutrient management on productivity of different crops at Bijapur

Center	Crop	Treatments	Yield (kg/ha)
Bijapur	*Rabi* sorghum	Fully organic (75% NP)	1436
		Fully organic (100% NP)	1716
		Integrated (50% org + 50% inorg)	1706
		Fully inorganic (RDF)	2032
		RD (FYM + Fertilizers)	2042
Bijapur	Chickpea	Fully organic (75% NP)	773
		Fully organic (100% NP)	842
		Integrated (50% org + 50% inorg)	1009
		Fully inorganic (RDF)	899
		RD (FYM + Fertilisers)	909

3.5.1.5 Tillage and nutrient management

At Solapur, low till + two harrowings along with one hoeing and one hand weeding together with 50 percent organic + 50 percent inorganic fertilizer recorded highest grain yield of pearlmillet (2521 kg/ha) over conventional tillage (2272 kg/ga). Low tillage + weedicide + 100 percent inorganic gave a minimum yield of 1711 kg/ha. In respect of *rabi* sorghum, there is no significant difference in grain yields among low (1977 kg/ha), medium (2172 jg/ha) and conventional tillage (2395 kg/ha) practices **(Tables. 58 and 59).**

Table.58. Influence of tillage and nutrient management of practices on productivity of different crops in sorghum based production system

Center	Crop	Treatments	Yield (kg/ha)	Mean over years	SYI
Bellary	Sorghum (5)	**Tillage**			
		CT (1ploughing + 2 harrowing + 2 heoings + 1 HW)	1953	1443	0.24
		LT (2 harrowings + 1 hoeing + 1 HW)	1815	1382	0.22
		MT (1 harrowing + 1 hoeing + weeding)	1703	1296	0.19
		INM practices			
		100 % N through organic) (50%(FYM) + 50% (GL))	1742	1285	0.19
		50% N (organic) + 50% N (Inorganic)	1811	1394	0.23
		100% N through inorganic (Urea)	1917	1430	0.24
Solapur	Pearlmillet (5)	**Tillage**			
		Low tillage + 50% organic + 50% inorganic (urea)	2521		
		Conventional tillage + 50% organic + 50% inorganic (urea)	2272		
		Low tillage + weedicide + 100 % inorganic fertilizer	1711		

(Figures in parentheses indicate no. of years of the experiments conducted)

Table.59. Influence of tillage and nutrient management of practices on productivity of different crops in sorghum based production system

Center	Crop	Treatments	Yield (kg/ha)	Mean over years
Bijapur	Sunflower	CT- Sunhemp incorp. 5t/ha	937	741
		Sunhemp incor. 2.5 t/ha +50% RDF (inorg.)	1533	1168
		100 RDF (inorg.)	1703	1268
		Farmer practice	937	798
		Farmer practice + susnhemp GM	1671	1273
		LT-1 Sunhemp incorp. 5t/ha	766	622
		sunhemp incor. 2.5 t/ha +50% RDF (inorg.)	1490	1128
		100% RDF (inorg.)	1490	1182
		Farmer practice	894	864
		Farmer practice + sunhemp GM	1405	1181
		LT-2 Sunhemp incorp. 5t/ha	681	608
		sunhemp incor. 2.5 t/ha +50% RDF (inorg.)	1490	1218
		100% RDF (inorg.)	1533	1343
		Farmer practice	894	895
		Farmer practice + sunhemp GM	1405	1199

Center	Crop	Treatments	Yield (kg/ha)	Mean over years
Solapur	*Rabi* sorghum	CT (Plough once in 3 years + one harrowing + ridges and furrows + one harrowing + SSDH + three hoeing) + 25 kg/ha N (Urea) + 25 kg/ha N (Org) (50% CR + 50% GLL) + 12.5 kg/ha P through SSP)	2395	
		MT (One harrowing + SSDH + one hoeing) + 25 kg/ha N (Urea) + 25 kg/ha N (Org) (50% CR + 50% GLL) + 12.5 kg/ha P through SSP)	2172	
		LT (Sowing with seed drill and light harrowing after sowing SDH) + 25 kg/ha N (Org) (50% CR + 50% GLL) + 12.5 kg/ha P through SSP)	1977	

CT-Conventional tillage, LT- Low tillage, GM- Green manure, RDF- Recommended dose of fertilizer, CR- Crop residue

3.5.1.6 Energy management

At Solapur, seeding devices with tractor drawn planters on *rabi* sorghum indicated that multi-crop planter was more suitable for sowing of *rabi* sorghum as compared to other planters, because the average seed rate for sowing of *rabi* sorghum obtained by multi-crop planter (10.2 kg/ha) which was nearer to the recommended drill (12 kg/ha). Seed rate (10.25 kg/ha) obtained by CRIDA planter was also nearer to the recommended seed drill, while the seed rate obtained in local seed drill was worked out more than recommended seed rate (13 kg/ha). There was no much variation in field efficiencies of different planters except local drill. However, the field capacity was highest in local seed drill (0.72 ha/hr) followed by multi-crop planter (0.67 ha/hr) and CRIDA planter. Two persons were required in local seed drills, one for dropping the seed and the other for dropping fertilizer manually in addition to one tractor operator. In respect of improved implements for tillage in orchards, it is indicated that the depth of ploughing in power tiller with rotavator, bullock drawn plough and tractor drawn plough were 11, 17.5 and 22.8 cm respectively. The field deficiency was more in tractor drawn plough (72%) as aginst 49% in bullock drawn mould board plough. The performance of manual dibbler for sowing of *rabi* sorghum indicated that the seed rate achieved by dibbler (10.2 kg/ha) was nearer to the recommended seed rate (10 kg/ha). The depth of seed placement (6.2 cm) was more compared to sowing by Mogada (5.2 cm). Sowing by dibbler recorded higher field efficiency (67 %), reduced the cost of operation (Rs. 300/ ha) compared to Mogada. In respect of interculture implements, cycle-hoe reduced the cost of operation (Rs.1250) increased the area coverage (0.29) compared to weeding manually in *rabi* sorghum. The design of cycle-hoe is very simple, can be manufactured in village level and cost is also low (Rs. 450). The blades can be replaced to suit different row spacing for different crops.

Evaluation studies with ridger-seed-cum-fertilizer drill for sunflower and sorghum in Bijapur indicated that germination and crop stand was better compared to the seed sown from the ordinary seed drills. The yields from sorghum recorded in ridger-seed-cum-fertilizer drill, bullock drawn seed drill and tractor drawn seed drill were 1700, 1660 and 1730 kg/ha respectively. The average soil moisture in the ridger-seed-cum-fertilizer drill (15.26%), while it was 13.83 % and 14.56% in bullock drawn and tractor drawn seed drill **(Table. 60).**

3.5.1.7. Crop management

Sowing of *rabi* sorghum at 45 to 20 cm gave highest grain yield (285 kg/ha) followed by 45x15 cm at Solapur. Phule Mauli recorded highest grain yield (265 kg/ha) followed by Maldandi 35-1 (194 kg/ha). At Solapur planting of sorghum at 45 x 25 cm gave significantly highest grain yield (1325 kg/ha) closely followed by 45 x 20 cm (1155 kg/ha). Application of 75:37.5 kg NP/ha recorded the highest grain yield (1277 kg/ha) followed by 60:30 kg NP/ha (1145 kg/ha) **(Table 61).**

Integrated weed management for pigeonpea highest grain yield of pigeonpea was noticed with weed free check (887 kg/ ha) which was on par with an application of *Fluchlorin* 45 EC @ 1 kg a.i/ha + 1 hoeing at 45 DAS (818 kg/ha) **(Table 62).**

Table. 60. Influence of energy management practices on productivity of different crops in sorghum based production system

Center	Crop	Treatment	Yield (kg/ha)
Bijapur	Sorghum	Bullock drawn seed drill	1660
		Tractor drawn seed-cum-fertilizer drill	1730
		Ridger fertilizer seed –drill	1700

Table.61. Influence of crop management practices on productivity of sorghum at Solapur

Center	Crop	Treatments	Yield (kg/ha)	Mean over years
Solapur	*Rabi* sorghum (3)	**Spacings**		
		30 x10 cm	109	767
		37.5 x 10cm	129	884
		45 x 15cm	258	930
		45 x 20cm	285	1017
		Varieties		
		Maldandi 35-1	194	919
		SPV-1359 (Phule Yeshoda)	127	780
		RSLG-262 (Phule Mauli)	265	998
Solapur	Sorghum	**Spacing**		
		45 x 25 cm	1325	1594
		45 x 20 cm	1155	1677
		45 x 15 cm	981	1486
		Fertilizers (kg/ha)		
		50:25 NP	1039	
		60:30 NP	1145	
		75:37.5 NP	1277	

(Figures in parentheses indicate no. of years of the experiments conducted)

Table. 62. Influence of weed management practices on productivity of pigeonpea in sorghum based production system

Center	Crop/ System	Treatments	Yield (kg/ha)	Mean yield over the years
Solapur	Pigeonpea (2)	Fluchloralin @ 1kg a.I. /ha (pre-emergence)	706	564
		T 1 + one hoeing after 45 DAS	818	652
		Pendimithalin @ 1 kg a.I. /ha (pre-emergence)	683	531
		T3 + one hoeing after 45 DAS	763	609
		Three hoeings at 15 days interval	764	655
		Competitive crop effect (blackgram)	595	437
		Weedy check	493	370
		Weed free check	887	725

(Figures in parentheses indicate no. of years of the experiments conducted)

3.5.1.8 Alternate land use system and farming systems

At Bijapur, the pearlmillet and pigeonpea grown in between tamarind seedlings with varied spacings indicated that the pearl millet yield was highest in planting geometry of 10m x 6m (317 kg/ha), followed by 10 x 9 m with 272 kg/ha and in 10 x 3 m with 258 kg/ha. The seed yield of pigeonpea was very low due to erratic distribution of rainfall. In sapota based agric-horti-silvi system in medium black soils, highest gross returns was recorded with sunflower intercrop in sappota (Rs.9675/ha), followed by sapota + peal millet (Rs. 8298/ha). The intercrops of sunflower and peal millet with sapota gave 297 and 253 kg/ha respectively. In aonla based agri-silvi horti system in medium vertisols by sunflower recorded seed yield of 828 kg/ha. In guava based system the establishment of henna and simaruba was 100 percent but the establishment of guava was very low. The sunflower crop grown in between guava + simaruba plantation was highest (417 kg/ha), followed by guava + henna system (333 kg/ha) in shallow to medium vertisols.

At Solapur, the alley of aonla at 8 x 18 m^2 + drumstick at a distance of pearlmillet in the line of aonla was planted, the annual crops of pearlmillet, pigeonpea, sunflower, pearlmillet + pigeonpea (2:1) and sunflower + pigeonpea (2:1) were grown as intercrops as a part of fifth year experiment. The results indicated that the drumstick yield in association with different crops/cropping systems ranged from 282-321 kg/ha. However, there was no significant difference in the yield of drumstick due to different intercrops. Among the systems, aonla + drumstick + sunflower + pigeonpea (2:1) recorded highest drumstick equivalent yield (2249 kg/ha), followed by aonla + drumstick + pearlmillet + pigeonpea (2:1) (1972 kg/ha). In respect of economic parameters, the gross returns of drumstick as a main

Agrihorticulture with tamarind + pearlmillet at Bijapur

crop were ranged from Rs. 451 – 5537/ha, while net returns from different intercrops and intercropping systems were ranged from Rs. 5406-3097/ha. Among various combinations, aonla + drumstick + intercrop of sunflower and pigeonpea (2:1) system recorded highest net returns (24984/ha) and also BC ratio 3.27 under the dryland conditions of Solapur **(Table. 63).**

Table. 63. Influence of alternate land use systems on productivity of arable crops in sorghum based production system

Center	Crop/ System	Treatment	Yield (kg/ha)		Drumstick Eqt. Yield (kg/ha)
			1	2	2
Solapur	Agri-horti system *Drumstick pod yield @ Grain yield of intercrops	Aonla + annual drumstick	282*	338@	620
		Aonla + drumstick + pearlmillet	317	2194	1279
		Aonla + drumstick + pigeonpea	288	1268	1905
		Aonla + drumstick + sunflower	321	1492	1759
		aonla + drumstick	304	1913 (716)	1972
		Aonla + drumstick + sunflower + Pigeonpea (2:1)	313	1244 (634)	2249

3.5.2 Pearlmillet based production system

3.5.2.1 Crops and varieties

At S.K.Nagar (Dantiwada), the improved cultivars of pearlmillet screened for drought resistance showed that the highest grain and fodder yield of pearlmillet was recorded by GHB-558 (1075 kg/ha) and GHB-577 (996 kg/ha) respectively. In *Herbacium* cotton variety G-COT-21 recorded highest yield (1051 kg/ha), followed by V-797 (936 kg/ha) and G-COT-13 (892 kg/ha) which were superior by 45.5. 29.7 and 23.5 percent over the local variety (722 kg/ha) respectively. In castor, the highest seed yield was recorded by RG-298 (1387 kg/ha), followed by RG-122 (1309 kg/ha) and RG-214 (1167 kg/ha). In respect of hybrids, JHB-887 recorded highest seed yield (1114 kg/ha), followed by SVHC-235 (1088 kg/ha). The castor hybrid GCH-5 gave 1380 kg/ha against the local with a yield of 828 kg/ha **(Tables. 64).**

At Hisar, the improved varieties of pearlmillet HHB-67-2 (2236 kg/ha), HHB-67 (1821 kg/ha) and HHB-94 (1201 kg/ha) recorded stable yields in erratic distribution of rainfall years like 2005. In respect of cowpea, Charodi, GC-3 and HC-98-96 recorded grain yields of 221, 235 and 248 kg/ha. In clusterbean, HG-563 gave highest grain yield (1504 kg/ha), followed by RGC-936 (1352 kg/ha) and HG-365 (1325 kg/ha). In improved cultivars of greengram, K-851 and MH-96-1 (Muskan) registered a grain yield of 1090 and 795 kg/ha even in ill distribution rainfall years. Among *rabi* crops, improved varieties of barley, BH-393 (1456 kg/ha) and BH-87 (1318 kg/ha) and mustard RH-819 (2146 kg/ha) and RH-30 (2008 kg/ha), Gobi sarson HNS-9605 (1443 kg/ha), taramira T-27 (542 kg/ha), chickpea H-208 (966 kg/ha) and HC-5 (934 kg/ha) were superior compared to other varieties and respectively.

Table. 64. Influence of improved cultivars on different crops in pearlmillet based production system

Center	Crop	Varieties	Yield (kg/ha)
Dantiwada	Castor (1)	Gch-8	951
		SHVC-235	1088
	(Initial hybrid trial)	JHB-887	1114
		NBCH-265	1077
	Castor (2) (Drought screening trial)	RG-122	1309
		RG-214	1167
		RG-247	1117
		RG-295	1130
		RG-298	1387
	Castor (Hybrid trial)	GCH – 4	1179
		GCH – 5	1380
		GCH – 6	1288
		Local	828
Dantiwada	Pearlmillet	GHB-526	804
		GHB-538	828
		GHB-558	1075
		GHB-577	996
	Cotton	V-797	936
		G. Cot-13	892
		G. Cot-21	1051
		Local	722

(Figures in parentheses indicate no. of years of the experiments conducted)

At Agra, improved varieties of sesame of TKG-201 (548 kg/ha) and OS-SEL-117 (777 kg/ha), niger JNS-27 (410 kg/ha), JNS-26 (399 kg/ha) and BNC-16 (401 kg/ha); clusterbean AVKG-73 (1702 kg/ha), HG-02-1 (1859 kg/ha) and CAZG-04-1 (1739 kg/ha) recorded higher and stable grain yields in rainfed environment **(Table. 65).**

Table. 65. Influence of improved varieties on productivity of different crops in pearlmillet based production system

Center	Crop	Treatment	Yield (kg/ha)	Mean over years	SYI
Hisar	Pearlmillet	HHB-67-2	2236	2236	
		HHB 67	1821	1837	0.35
		HHB 94	1201	1477	0.23
		HC 10	1256	1558	0.25
		HC 20	1076	1582	0.26
	Cowpea	Charodi	221	726	0.32
		GC-3	235	551	0.18
		HC 98-96	248	646	0.26
	Sesame	HT-1	70	390	
	Clusterbean	RGC 936	1352	573	0.12
		HG 365	1325	691	0.20
		HG 563	1504	1218	0.55
		HGS-870	938	830	0.29
	Greengram	K-851	1090	928	
		S-9	690	590	0.34
		MH96-1(Muskan)	759	846	
	Blackgram	T-9	80	379	
	Mothbean	RMD-40	451	—	
		DMH-2	437	—	
	Rabi Mustard	RH 30	2008	1429	0.34
		RH 819	2146	1507	0.37
		RH-8812 (Luxmi)	1870	1489	0.36
		RH-9304	1594	2331	0.72
		RH-9801	1732	2275	0.70
		RH-9901	1663	2142	0.64
	Barley	BH 75	1180	2364	0.44
		BH 87	1318	2125	0.39
		HB 393	1456	2127	0.39
	Taramira	T-27	542	447	
	Gobhi sarson	HNS-9605	1443	1415	
	Chickpea	H-208	966	877	
		C-235	828	836	
		HK-1	642	665	
		HC-1	772	786	
		HC-3	848	974	
		HC 5	934	934	
Dantiwada	Mustard (MLT)	GM – 2	1009	1027	
		GM – 3	1221	1187	
		Bio – 902	1248	1256	
		Local	816	834	
Agra	Sesame (IVT)	Local check	298		
		RT-54 (NC)	621		
		MT-14-04	601		
		TKG-22 (NC)	578		
		OSC-560	562		
Agra	Sesame (AVT)	Local check	279		
		OS-Sel-117	777		
		RT-54 (NC)	552		
		TKG-201	548		
	Niger (AVT)	JNS-27	410		
		JNS-26	399		
	Niger (IVT)	BNC-16	401		
		JNS-116	373		
	Clusterbean (AVT)	HGS-02-1	1859		
		CAZG-04-1	1739		
		AVKG-73	1702		

Improved varieties of different kharif crops at Hisar

3.5.2.2 Cropping systems

In Agra, pigeonepa + clusterbean (2:2) gave highest net returns (12324/ha), followed by sole pigoenpea (Rs. 10979/ha) and pigeonpea + Lady's finger (2:2) (Rs. 10494/ha). In respect of yields, pigeonpea + clusterbean (2:2) recorded highest grain equivalence of pigeonpea (1376 kg/ha) followed by pigeonpea + lady's finger (2:2) system (1270 kg/ha). The component crop yields under pigeonpea + clusterbean systems were 915 kg/ha of pigeonpea nd 645 kg/ha of clusterbean.

At Dantiwada, paired row sowing of greengram (30-60-30-60 cm) in between 2 pairs of castor showed highest seed yield of greengram (340 kg/ha), which is on par with sole greengram sown with onset of monsoon (350 kg/ha) **(Table. 66).**

In respect of castor relay cropping system at Hisar, castor planted in paired row system (60:120 cm and 60 cm) and 2 rows of greengram recorded highest castor equivalent grain yield (1910 kg/ha) with 36 percent additional land equivalent ratio (LER 1.36) in rainfed environment **(Table 67).**

3.5.2.3 Rain water management

The drought management studies at Dantiwada showed that highest grain yield of pearlmillet was recorded with pearlmillet + sunhemp (4:2) along with green manuring at 30 DAS with paired rows of 30/60 cm (2647 kg/ha), followed by pearlmillet + sunhemp (4:2) with 45 cm spacing along with straw mulch at 30 DAS (2567 kg/ha) in early sown conditions. Under late sown condition, maximum fodder yield of pearlmillet (7574 kg/ha) was recorded with pearlmillet + sunhemp (4:2) system along with the mulching at 30 DAS after sowing. In castor, formation of ridges and furrows gave highest seed yield (862 kg/ha), followed by flat bed (704 kg/ha). The land configuration of ridges and furrows without FYM gave highest seed yield of castor (898 kg/ha) followed by ridges and furrows with 10 t of FYM/ha (826 kg/ha) **(Table. 68).**

In mustard, 4 cm of irrigation at 50 percent flowering and also 4 cm irrigation at 50 percent at silique formation recorded highest seed yield (2085 kg/ha) followed by irrigation of 4 cm

Table. 66. Influence of cropping systems on productivity of different crops in pearlmillet based production system

Center	Crop/ System	Treatment	Yield (kg/ha) – 2005-06		Mean yield over the years		SYI	
			1	2	1	2	1	2
Agra	Pigeonpea (6)	Sole Pigeonpea	1115	—	903	—	0.73	—
		Sole Chilli	480	—	420	—	0.34	—
		Sole Clusterbean	835	—	862	—	0.29	—
		Sole Lady's finger	820	—	992	—	0.25	—
		Pigeonpea + Chillie (1:1)	880	398	675	269	0.73	—
		Pigeonpea + Clusterbean (1:1)	915	645	648	571	0.66	—
		Pigeonpea + Lady's finger (1:1)	910	630	694	628	0.72	—
Danti wada	Greengram + castor (Relay cropping)	Sole greengram (45 cm) onset of monsoon	350		636		0.43	
		Sole castor (90 x 60 cm) on set of monsoon		591		1239		0.68
		Pair row sowing of greengram (30-60-30 cm) between 2 pairs	340	—	701	306	0.48	0.10
		Pair row sowing of greengram (30-60-30 cm) castor grown as relay in between 2 pairs)	321	—	630	254	0.43	0.07
		Greengram + castor (1:1) castor grown as a relay crop	295	—	644	227	0.44	0.36

(Figures in parentheses indicate no. of years of the experiments conducted)

Table. 67. Influence of relay cropping systems on productivity of castor at Hisar

Center	Crop/ System	Treatment	Yield (kg/ha)		
			1	2	GEY
Hisar	Castor	Castor sole 75cm x 60 cm	1405	-	1405*
	*Castor equivalent yield	Castor paired 60:90 x 60 cm	1379	-	1379
		Castor paired 60:90 x 60 cm + one row of greengram	1305	267	1854
		Castor paired 60:90 x 60 cm + one row of mothbean	1325	@	1325
		Castor paired 60:90 x 60 cm + one row of Clusterbean	1367	247	1644
		Castor paired 60:90 x 60 cm + one row of cowpea	1243	164	1519
		Castor paired 60:90 x 60 cm + one row of Pearlmillet	1250	175	1367
		Castor 90cm x 60cm	1339	-	1339
		Castor paired 60:120 cm x 60cm	1317	-	1317
		Castor paired 60:120 cm x 60cm + two rows of greengram	1235	329	1910
		Castor paired 60:120 cm x 60cm + two rows of mothbean	1272	@	1272
		Castor paired 60:120 cm x 60cm + two rows of clusterbean	1295	308	1642
		Castor paired 60:120 cm x 60cm + two rows of cowpea	1235	205	1570
		Castor paired 60:120 cm x 60cm + two rows of pearlmillet	1174	206	1302

@ Mothbean data could not be recorded because of continuous rains after harvest resulted in delay of produce

Table. 68. Influence of rain water management of practices on productivity of different crops in pearlmillet based production system

Center	Crop/	Treatments	Yield (kg/ha)	Mean yield over the years	SYI
		Mulches			
Dantiwada	Castor	Crop residue mulch (Castor)	1199	1518	0.48
		Dust mulch (soil mulch)	755	1224	0.33
		Antitranspirants			
		Kaolin @5%	1150	1602	0.52
		P.M.A. @ 0.1%	919	1248	0.34
		Cetyl Alcohol @ 0.75%	1015	1410	0.42
		Water spray	959	1352	0.39
		Absolute control	841	1243	0.34
	Castor	PMA 0.05 %	733	875	0.12
		PMA 0.1%	688	855	0.11
		PMA 0.15 %	644	798	0.09
		Kaolin 2%	783	1070	0.22
		Kaolin 4%	901	1131	0.25
		Kaolin 6%	999	1238	0.30
		Cetyle alcohol 0.5 %	725	1067	0.22
		Cetyle alcohol 0.75 %	810	1118	0.24
		Cetyle alcohol 1.0 %	808	1062	0.21
		Control (water spray)	770	1051	0.21
		Absolute control	558	957	0.16
	Pearlmillet Early sown*	Pearlmillet (rows 45 cm)	2091	2122	0.73
		Pearlmillet + sunhemp 2:1 (GM 30 DAS) paired row 30/60cm	2109	1947	0.66
		Pearlmillet + sunhemp 2:1 (Mulching 30DAS) paired row 30/60cm	2154	1977	0.68
		Pearlmillet + sunhemp 4:2 (GM 30DAS) paired row 30/60cm	2647	2303	0.80
		Pearlmillet + sunhemp 4:2 (Mulching 30DAS) paired row 30/60cm	2304	2016	0.69
		Pearlmillet third row removed 30 DAS for fodder (rows 45 cm)	1931	1684	0.56
		Pearlmillet third row removed 30 DAS for fodder and furrow making rows, 45cm	1772	1673	0.56
		Pearlmillet (rows 45cm) + straw mulching (30DAS)	2567	2165	0.75
		Pearlmillet (rows 45cm) + soil mulching (30DAS)	2217	2039	0.70
Danti wada	Late Sown *Fodder yield	Pearlmillet (rows 45cm)	1173	6519*	
		PM + sunhemp 2:1 (GM 30DAS) paired row 30/60cm	1160	6444	
		PM + sunhemp 2:1 (Mulching 30DAS) paired row 30/60cm	1190	6611	
		Pearlmillet + sunhemp 4:2 (GM 30DAS) paired row 30/60cm	1283	7130	
		PM + sunhemp 4:2 (Mulching 30DAS) paired row 30/60cm	1363	7574	

Center	Crop/	Treatments	Yield (kg/ha)	Mean yield over the years	SYI
		Pearlmillet third row removed 30 DAS for fodder (rows 45 cm)	1010	5611	
		Pearlmillet third row removed 30 DAS for fodder and furrow making rows, 45cm	1037	5759	
		Pearlmillet (rows 45cm) + straw mulching (30DAS)	1337	7426	
		PM (rows 45cm) + soil mulching (30DAS)	1220	6778	
Agra	Mustard (3)	No irrigation (control)	1487	1437	—
		Irrigation at 50% flowering	1934	1896	
		Irrigation at 50% silique formation	1854	1805	
		4 cm irrigation at 50% flowering and 4 cm irrigation at 50% silique formation	2085	2059	

(Figures in parentheses indicate no. of years of the experiments conducted)

at 50 percent flowering only (1934 kg/ha). Supplemental irrigation at 50 percent flowering and also at silique formation @ 4 cm at each stage enhanced the productivity of maize by 598 kg/ha over control. Among the levels of nitrogen applied with supplemental irrigation, 80 kg N/ha enhanced the productivity by 26% compared to the control. Interaction of irrigation and nitrogen levels showed that 80 kg N with 4 cm irrigation each at flowering and silique formation registered the highest grain yield of maize (2385 kg/ha), followed by 12 kg N at the same irrigation level (2329 kg/ha).

Among various anti-transpirants, spraying of 6 percent of Kaolin solution at 45 and 75 DAS gave significantly higher yield of castor (999 kg/ha), which is equivalent to the spray of Kaolin 4 percent (901 kg/ha) **(Table 69).**

3.5.2.4 Integrated nutrient management

At Hisar, treating pearlmillet and mustard with azotobacter strains of MAC-68 was recorded the highest grain yield (1103 kg/ha), followed by MAC-27 (1060 kg/ha). Treatments of pearlmillet with these strains on an average enhanced the productivity by 12 percent compared to the control. In mustard, MAC-27 strain of azotobacter recorded the highest yields (2195 kg/ha), followed by MAC-68 (2183 kg/ha) and HT-54 (2170 kg/ha) **(Table. 70).**

At Agra, 15 kg N through compost and 20 kg N through inorganic fertilizer gave highest grain yield of pearlmillet in sole (1925 kg/ha) and strip cropping (983 kg/ha). In clusterbean, 50 percent of recommended N through inorganic fertilizer gave the highest productivity of in sole cropping (2346 kg/ha). In strip cropping system, 50 percent N through inorganic fertilizer and 15 kg N through compost + 10 kg N through inorganic fertilizer were at par with a yield of 1162 and 1175 kg/ha. Recommended N through inorganic fertilizer (60 kg/ha) gave highest pearlmillet equivalent yield (4762 kg/ha), followed by 15 kg N (compost) and 20 kg N through inorganic fertilizer (4583 kg/ha). In respect of uptake of nitrogen, recommended dose of N (60 kg/ha) registered more nitrogen content in grain and also in stover compared to other combinations in both sole and strip cropping systems **(Table. 71).**

Table. 69. Influence of land configuration on productivity of castor at Dantiwada

Treatments	Yield (Kg/ha)
Flat bed with No FYM	648
Ridges and furrows with no FYM	898
Trench method with no FYM	645
FYM 10 t/ha + flat bed	759
FYM 10 t/ha + Ridges and furrows	826
FYM 10 t/ha + Trench method	730

Table. 70. Influence of azotobacter strains on productivity of pearlmillet-mustard system at Hisar

Treatments	Yield (kg/ha)		Mean yield over years		SYI	
	Pearlmillet	Mustard	Pearlmillet	Mustard	Pearlmillet	Mustard
Control	968	—	1258	2138	0.49	0.75
MAC - 27	1060	2035	1330	2217	0.52	0.78
MAC - 68	1103	2195	1454	2380	0.58	0.83
HT-54	1048	2170	1411	2341	0.56	0.82
Ala27	999	2059	1353	2232	0.53	0.78
MSX9	1023	2096	1354	2252	0.53	0.79

Table. 71. Influence of integrated nutrient management practices in pearlmillet-clusterbean system at Agra

Treatments	Sole cropping		Strip cropping		Pearlmillet equiv. yield (kg/ha)
	Pearlmillet	Clusterbean	Pearlmillet	Clusterbean	
Control	1116	2115	592	1062	3778
Rec.N through inorganic fert.(60 kg/ha)	2226	2346	1132	1210	4762
50% rec.N through (inorganic)	1716	2245	872	1162	4398
25 kg N (compost)	1675	2149	867	1006	3885
15 kg N (compost) + 10 kg N (inorganic)	1692	2265	875	1175	4400
15 kg N (compost) + 20 kg N (inorganic)	1925	2210	983	1200	4583
15 kg N (greenleaf) + 10 kg N (inorganic)	1664	2310	856	1190	4426
15 kg N (greenleaf) + 20 kg N (inorganic)	1815	2290	932	1182	4478
15 kg N (compost) + 10 kg N (greenleaf)	1675	2185	860	1110	4190

In INM studies, pearlmillet-pearlmillet sequence indicated that application of 50 percent N through fertilizer and 50 percent through FYM recorded highest grain yield (2682 kg/ha), which is on par with RDF (60 kg N + 40 kg P) along with 25 kg Zn SO_4 (2542 kg/ha). However, use of 50 percent N through Farm Residue and 50 percent N (inorganic fertilizer with 2476 kg/ha was as good as application of 100 percent RDF through fertilizer (2442 kg/ha) **(Table. 72).**

In clusterbean, there is no significant difference in yield among levels of sulphur, but 40 kg P application gave highest productivity of clusterbean (2242 kg/ha), which showed an additional increase in yield of 427 kg/ha compared to control. At Dantiwada, the agro-forestrty studies indicated that highest clusterbean equivalent yield was recorded with an application of 100 percent recommended N for clusterbean grown together with *Dalbergia sissoo* (352 kg/ha). Among crops, clusterbean grown in between tree species gave higher yield (370 kg/ha) over sorghum (263 kg/ha). Among fertilizer levels, use of 100 percent of recommended N in agro-forestry system enhanced the productivity of both components in terms of clusterbean equivalent yields (357 kg/ha), followed by 50 percent recommended N (326 kg/ha).

The long-term studies on castor indicated that 50 percent N (FYM) + 50 percent N (inorganic) and 100 percent recommended N through fertilizer recorded castor yields of 751 and 652 kg/ha respectively which were at par in rainfed environment. In sorghum, 75 percent recommended N through urea + 25 per cent through glyricidia and 50% RDN through urea and 50 percent through glyricidia gave on par dry fodder yields of sorghum ranging from 7003 – 7228 kg/ha. However, 75 percent of RDN through urea and 25 percent through compost along with azotobacter gave highest dry fodder yield of sorghum (8047 kg/ha).

In an INM study at Dantiwada with senna indicated that application of 40 kg N/ha along with *azospirillum* inoculation gave highest dry weight of yield (3581 kg/ha) from 2 cuttings. Application of 2 t of FYM/ha produced 16 and 21 percent higher total dry weight of leaves and seed yield of senna respectively.

3.5.2.5 Tillage and nutrient management

At Agra, conventional tillage (CT) with interculture produced significantly higher grain yield of pearlmillet (2152 kg/ha) over low tillage + interculture (1727 kg/ha) and low tillage + interculture + weedicide (1771 kg/ha). The increase in grain yield of pearl millet due to conventional tillage was 20 and 18 percent over low tillage + interculture and low tillage with interculture along with weedicides. Application of 100 percent N through inorganic source recorded highest grain yield of pearl millet (1999 kg/ha) than 100 percent N through organic source (1761 kg/ha). However, the difference in grain yield due to 50 percent N through organic source and 50 percent N through inorganic source and 100 percent N through inorganic source were at par.

In cluster bean at Dantiwada, low till (50 percent of CT) + weedicide and interculture significantly gave higher grain yield (414 kg/ha), followed by low till with interculture (377 kg/ha). Among nutrient management practices, application of 50 percent N through urea and 50 percent through FYM recorded highest grain yield (389 kg/ha) as well as stalk yield (897 kg/ha) **(Table. 73).**

3.5.2.6 Energy management

In Hisar, tractor drawn Ridger seeder registered the highest grain yield of pearl millet (1494 kg/ha), which is at par with tractor drawn bed planter (1401 kg/ha). These two seeding devices enhanced the productivity of pearl millet by 79 percent over hand plough. There is no significant difference in chickpea due to tractor drawn Ridger seeder (2085 kg/ha) and Desi plough (2131 kg/ha). The seeding device ridger seeder out yielded the seed yield of mustard under both normal and receding moisture conditions. There was no significant difference in seed yield of mustard with ridger seeder and hand plough in both normal and receding moisture conditions at Hisar **(Table. 74).**

Table.72. Influence of integrated nutrient management practices on productivity of different crops in pearlmillet based production system

Center	Crop/ System	Treatments	Yield (kg/ha)	Mean yield over years	SYI
Agra	Pearlmillet (1997-2005)	Control	1224	1105	0.20
		RDF. (60 kg N+ 40 kg P/ha)	2442	2095	0.55
		50% Rec.fert.	1732	1584	0.37
		50% N (farm residue)	1775	1600	0.37
		50% N (FYM)	1824	1669	0.40
		50% N (fert.) + 50% N (farm residue)	2476	2034	0.53
		50% N (fert.) + 50% N (FYM)	2682	2208	0.59
		RDF + 25 kg $ZnSO_4$/ha	2542	2148	0.57
		Farmer's method (10-15 kg N/ha)	1310	1257	0.25
	Clusterbean	Levels of Sulphur (kg/ha)	1864	1172	0.36
		0	2190	1317	0.43
		30	2088	1283	0.41
		Levels of Phosphorus (kg/ha)			
		0	1815	1037	0.30
		20	2034	1242	0.39
		40	2242	1393	0.46
		60	2096	1358	0.45
Danti wada	Trees and Crops *(Clusterbean eqt.)	No fertilizer for sorghum together with *Simarouba glauca*	278*	356	0.40
		100% recommended N for clusterbean together with *Simarouba glauca*	344	396	0.46
		100% recommended N for clusterbean together with *Dalbergia sissoo*	352	421	0.51
Hisar	Mustard	**Manures applied during Kharif**			
		Control	1492	1503	0.30
		FYM @4t/ha	1764	1752	0.39
		Vermiculture @4t/ha	1682	1689	0.37
		Dhaincha G.M.	1665	1569	0.32
		Cowpea G.M.	1638	1487	0.29
		Biofertiliser applied during *rabi*			
		Control	1507	1445	0.28
		Azotobacter	1638	1590	0.33
		Phosphobacterium	1564	1531	0.31
		Azoto+Phosphobact	1727	1678	0.37
		Rec.dose of fert.(40:20 kg NP/ha)	1806	1758	0.40
	Greengram	Control (No fertilizer and no inoculation)	816	879	0.48
		Inoculation of seed with Rhizobium	924	962	0.53
		N10P20/ha+innoculation of seed with PSB	1108	1289	0.72
	Mustard	Control (No nitrogen fertilizers & no inoculation)	1726	1765	0.63
		Control + inoculation of seed with HT-54	1788	1865	0.67
		Control + inoculation of seed with MAC-27	1800	1890	0.68
		20 kg N/ha	1825	2013	0.72
		40 kg N/ha	1924	2189	0.78
		20 kg N/ha + Azotobacter (HT-54)	1887	2088	0.75
		40 kg N/ha + Azotobactor (HT-54)	2047	2320	0.83
		20 kg N/ha + Azotobacter (MAC-27)	2010	2158	0.77
		40 kg N/ha + Azotobactor (MAC-27)	2059	2352	0.84
		40 kg N/ha + Azotobactor (HT-54 and MAC-27)	2170	2416	0.87
Hisar	Chickpea	Control (No fertilizer and no inoculation)	814	999	0.47
		N10P20 kg/ha	1036	1300	0.63
		N10 kg/ha + Innoculation of seed with PSB	937	1157	0.55
		P20 kg/ha + Innoculation of seed with Rhizobium	949	1198	0.58
		N10P20/ha+innoculation of seed with PSB	1097	1384	0.67
		N10P20/ha+innoculation of seed with Rhizobium	1110	1425	0.70
		N10P20/ha+innoculation of seed with PSB and Rhizobium	1159	1492	0.73

Center	Crop/ System	Treatments	Yield (kg/ha)	Mean yield over years	SYI
		N20/ha + innoculation of seed with PSB	974	1249	0.60
		P40/ha + inoculation of seed with Rhizobium	986	1293	0.63
		N20P40/ha	1208	1559	0.77
Hisar	Mustard	Control	1837	1814	0.65
		Control + Biomix	1924	1872	0.67
		50% rec.dose of fertilizer	1961	1961	0.71
		75% rec.dose of fertilizer	1985	2036	0.73
		100% rec.dose of fertilizer	2121	2295	0.84
		50% rec.dose of fertilizer+ Biomix	1985	1998	0.72
		75% rec.dose of fertilizer+ Biomix	2109	2211	0.80
		100% rec.dose of fertilizer + Biomix	2232	2411	0.88
		75% rec.dose of fertilizer + Azotobactor	2047	2154	0.78
		75% rec.dose of fertilizer + Azospirillum	2035	2139	0.78
		75% rec.dose of fertilizer + PSB	2010	2110	0.76
Danti wada	Castor (3)	Control (No manures and fertilizers)	322	312	0.06
		Farmers method (5t FYM/ha once in 3 years)	487	485	0.10
		100% Rec.N (fert.)	652	645	0.25
		50 % N (inorganic) + 50% N (FYM)	751	694	0.30
Hisar	Pearlmillet-pearlmillet	**Fertlizer levels (kg/ha)**			
		0	1012	1274	0.33
		50% RDF	1136	1398	0.39
		100% RDF	1179	1475	0.42
		FYM levels (t/ha)			
		0	1033	1240	0.32
		4	1101	1430	0.40
		8	1192	1474	0.42
		Bacterial Culture			
		No culture (uninoculated)	1039	1277	0.34
		Azotobacter (HT-54) inoculated seed	1199	1418	0.39
		Azotobacter (MAC-27) inoculated seed	1089	1450	0.41

Table.73. Influence of tillage and nutrient management practices on productivity of different crops in pearlmillet based production system

Center	Crop/ System	Treatments	Yield (kg/ha)	Mean yield over years	SYI
Agra	Pearlmillet (6)	**Tillage**			
		Conventional tillage + interculture	2152	1657	0.32
		Low tillage + interculture	1727	1557	0.28
		Low tillage + weedicide + Interculture	1771	1642	0.31
		Fertilizers			
		100% through organic	1761	1511	0.27
		50% through organic + 50% through inorganic	1889	1640	0.31
		100% through inorganic	1999	1623	0.31
Dantiwada	Cluster bean	**Tillage**			
		Conventional tillage + interculture	248	240	0.38
		Low till + interculture	377	318	0.54
		Low till + weedicide + interculture	414	403	0.72
		Fertilzers			
		50% of organic source (FYM)	333	296	0.49
		100% of organic source (FYM)	320	302	0.51
		50% inorganic (Urea) + 50% through FYM	389	372	0.66
		100% through inorganic (Urea)	343	311	0.53

(Figures in parentheses indicate no. of years of the experiments conducted)

Table.74. Energy management practices on productivity of different crops in pearlmillet based production system

Center	Crop/ System	Treatments	Yield (kg/ha)	Mean yield over years	SYI
Hisar	Pearlmillet (3)	Bullock drawn seed drill	1096	1589	0.33
		Tractor drawn seed drill	1277	1658	0.36
		Tractor drawn bed planter	1401	1662	0.36
		Tractor drawn ridger seeder	1494	1904	0.45
	Mustard (3)	**Normal moisture**			
		Desi plough	962	1599	0.35
		Ridger seeder (two row)	962	1734	0.40
		Ridger seeder (Single row)	943	1412	0.28
		Bed planter	527	957	0.10
		Receding moisture			
		Desi plough	1055	1363	0.55
		Ridger seeder (two row)	1092	1610	0.68
		Ridger seeder (Single row)	907	1311	0.53
		Bed planter	518	991	0.37
	Chickpea (4)	Bullock drawn Desi plough	2131	1354	0.52
		Bullock drawn Dopara	1344	1166	0.43
		Tractor drawn Ridger seeder	2085	1534	0.61
		Tractor drawn Bed planter	510	913	0.31
		Tractor drawn Seed drill	1761	1369	0.53

(Figures in parentheses indicate no. of years of the experiments conducted)

3.5.2.7 Crop management

Among Crop Management practices, sowing of mustard at Agra between 11-20 October gave highest yield (1596 kg/ha), followed by sowing between 1-10 October (1350 kg/ha). Early sowing of mustard between 20-30 September reduced the seed yield by 50 percent compared to sowing between 11-20 October. In respect of plant population (RPP), recommended plant population of mustard ranging from 1.48 to 1.85 lakhs/ha was found optimum in realizing higher yield (1318 kg/ha) under rainfed environment **(Table. 75).**

3.5.2.8 Alternate land use system and farming systems

At Dantiwada in ley farming studies, pearlmillet grown after fodder recorded the highest pearlmillet equivalent grain yield (1132 kg/ha), which is on par with pearlmillet grown after *Dicanthium anulatum* (1155 kg/ha), *Cenchrus ciliaris* (1046 kg/ha) and *Stylosanthes hamata* (1056 kg/ha) **(Table. 76)**.

The study indicated that the grass species of *Dichanthium annulatum* produced maximum gross returns (Rs. 6930/ha). Among arable crops, pearlmilelt grown in between strips of

Pearlmillet+karingdo (2:1) at S.K. Nagar

Table.75. Influence of crop management practices on yield of mustard at Agra

Crop	Treatments	Yield (kg/ha)	Mean yield over years	SYI
Mustard (3)	Sowing time			
	Sowing of crop between 20-30th September	837	883	0.39
	Sowing between 1st -10th October	1350	1207	0.59
	Sowing between 11th-20th October	1596	1447	0.74
	Sowing between 21st- 30th October	1023	1004	0.46
	Recommended plant population (RPP)			
	75% RPP (1.11 lakh/ha)	997	1001	0.46
	100% RPP (1.48 lakh/ha)	1318	1246	0.61
	125% RPP (1.85 lakh/ha)	1310	1210	0.59
	150% RPP (2.22 lakh/ha)	1181	1085	0.51

RPP: Recommended Plant Population

grasses produced highest gross returns of Rs.11142/ha, followed by sorghum with Rs.8100/-. Soil fertility was improved significantly by growing cluster bean or green gram crops in between strips.

The Karingdo grown as mixed crop with pearl millet gave highest pearl millet equivalent yield (3526 kg/ha) when Karingdo was grown in 3rd row of pearlmillet, followed by Karingdo in 4th row of pearlmillet (1:4) (3322 kg/ha). On an average these two systems gave higher gross returns of Rs.34106/- and Rs. 23228/- compared to sole pearl millet (Rs. 20969/ha). In crop diversification studies at Agra, sadabahar, vetiveria, lemongrass and Palma Rosa grass have more capacity to survive in moisture conditions. Citronella is more susceptible to moisture conditions, but Palma Rosa was rapid in their growth. Among various species, Veteveria produced the highest fresh (54270 kg/ha) and dry weight (40260 kg/ha) followed by lemongrass with 46260 and 31562 kg/ha of fresh and dry weight, respectively **(Table. 77)**.

The Agri-horti system at Agra with aonla indicated that clusterbean intercropping gave highest grain yield (920 kg/ha), followed by green gram and soybean giving the grain yield of 675 and 640 kg/ha, while pearl millet gave a yield of 1518 kg/ha **(Table 78).**

At Agra, the studies on establishment of medicinal and aromatic plants indicated that lemon grass, vettivaria recorded the highest survival percentage (96-97%) while Thulasi, Henna, and citronella grass recorded the survival 69, 78 and 91% respectively. In terms of height, palmarosa showed highest plant height (205 cm), followed by vetiveria (185 cm) **(Table-79).**

Table 76. Ley farming in marginal land at Dantiwada

Crop/ System	Treatments	Yield (kg/ha)	Mean yield over years	SYI
Ley farming	**Grasses**			
	Stylosanthes hamata	1056	2546	0.21
	Cowpea	1132	2035	0.11
	Dichanthium annulatum	1155	2465	0.19
	Cenchrus cilliaris	1046	2534	0.20
	Crops			
	Greengram	499	3037	0.04
	Clusterbean	684	2299	0.04
	Pearlmillet	1857	2856	0.42
	Sorghum	1350	2434	0.24

Table.77. Influence of alternate land use systems on productivity of arable crops at Dantiwada

Center	Crop/ System	Treatment	Yield (kg/ha) – 2005-06		Mean yield over years		SYI	
			1	2	1	2	1	2
Agra	Aonla (2005)	Aonla + *Stylosanthes hamata*	—	2788	—	2408	0.36	3485*
		Aonla + *Cenchrus ciliaris*	—	2403	—	1776	0.20	3003
	*Net returns Rs./ha)	Aonla + *Dichanthium annulatum*	—	2201	—	1951	0.25	2752
Dantiwada		Pearlmillet sole (45 x 15cm)	3495			3220		20969
		Karingdo sole (120 x 45cm)	2430			1713		14579
		Pearlmillet + karingdo (2:1)	3656			3130		21939
		Pearlmillet + karingdo (3:1)	3768			3060		22610
		Pearlmillet + karingdo (4:1)	3635			3185		21808
		Karingdo in 3rd row of Pearlmillet	4018			3526		24106
		Karingdo in 4th row of pearlmillet	3871			3322		23228
		Karingdo in 5th row of pearlmillet	3887			3306		25320

Table.78. Influence of alternate land use systems on productivity of arable crops at Agra

Center	Crop	Treatments	Yield (kg/ha)	
			1	2
Agra	Aonla	Aonla + greengram - mustard	675	1480
		Aonla + clusterbean – chickpea	920	856
		Aonla + soybean – barley	640	1825
		Aonla + sesame – lentil	310	615
		Aonla – pearlmillet	1518	—

Table. 79. Preliminary evaluation of few medicinal and aromatic plants for their performance in dryland conditions – Agra

Treatments	Survival (%)		Plant height (cm)	
	2005	Mean (4 yrs)	2005	Mean (4yrs)
Palma rosa	93	83	205.1	158
Lemon grass	96	86	136.9	95
Citronella grass	91	79	127.7	89
Vetiveria (Khus)	97	84	184.6	126
Sadabahar	95	90	72.3	67
Sweet basil (Tulsi)	69	71	76.2	74
Heena	78	65	49.5	40

The farming system modules at Agra showed that from 1 ha land, farmer could have 275 kg pulses, 210 kg oil seeds and 400 kg green fodder in surplus. By selling out these surplus commodities, a farmer can meet some part of their domestic requirement. To complete the task of this module, 180 man-days are required **(Tables. 80 and 81).**

Table.80. Bio-diverse farming system model - Agra

Crop	Area under cultivation (ha)	Production (kg)
Horticulture crops	0.2	
Aonla (Balwant)	10 plants	Establishment phase (No production)
Ber (Umrah)	10 plants	
Bel (Etawah type)	10 plants	
Cereal crops		
Pearlmillet (MBH-163)	0.1	200
Pulses		
Clusterbean (HGS-365)	0.1	160
Pigeonpea (UPAS-120)	0.1	100
Greengram (Samrat)	Greengram intercrop of pigeonpea	50
Pigeonpea (Local variety) Long duration	200 plants on field boundary	25
Chickpea (RGS – 44)	0.1	120
Chickpea (RGS – 44)	0.1 (after fodder)	80
Oilseed		
Mustard (Pusa Jaikisan)	Intercrop with chickpea	40
Mustard (Pusa Jaikisan)	0.2 (after GM)	320
Fodder	0.3	800
Green (WCC - 75 + Desi)		
Pearlmillet + cowpea	0.2	
Dry		
Pearlmillet straw		510
Pigeonpea straw		30
Greengram straw		15
Chickpea straw		100
Fuel		900
Mustard stick		
Pigeonpea stick		
Vegetable, Medicinal & Aromatic crops	0.2	140 & 100
Brinjal	0.05	Under estt. Phase
Marigold flowers	0.05	100
Medicinal plants	0.05	Under estt phase
On Field Boundary	330 m long	
Subabool		Under estt. phase
Caronda		

Table.81. Influence of bio-diverse farming system model on production and requirements of marginal family at Agra

Items	Production (kg)	Requirement (kg)	Balance (kg)
Cereal	200	750	-550
Pulses	375	100	275
Oilseed	360	150	210
Fodder-green	800	400	400
Fodder-dry	655	2000	-1345
Clusterbean (Grain)	160	1000	-840

3.5.3. Fingermillet based production system

3.5.3.1 Crops and varieties

At Bangalore, the genotypes chillis of PBC-613 recorded highest yield (2779 kg/ha), followed by GPC-82 (2682 kg/ha), Anantapur local (2509 kg/ha), PBC 972 (2508 kg/ha) and LAM-333 (2034 kg/ha). ISPN-12-9 gave lowest yield of 171 kg/ha in the trial **(Table. 82).**

Table.82. Evaluation of chilli genotypes for drought and disease tolerance (multi location trial)

Genotypes	Dry Chilli Yield (kg/ha)	
	2005	Mean (2yrs)
ISPN 12-9	171	581
Ananthapur local	2509	2442
GPC-82	2682	2757
PBC-613	2779	2823
PBC-972	2508	2192

In multilocation trial with chilli genotypes a yield in the range of 1056 to 1792 kg/ha was attained. Arka Lohit attained 1792 kg/ha, followed by Samrudhi with 1637 kg/ha and HMT-1 with 1608 kg/ha, while PUSA-Jwala gave the lowest yield of 1056 kg/ha in the trial **(Table. 83).**

Table. 83. Multilocation testing of promising chilli genotypes – Bangalore

Genotypes	Dry Chilli yield (kg/ha)	
	2005	Mean (2yrs)
AR – 75	1527	2391
Arka Lohit	1792	2409
Samrudhi	1637	2687
Pusa Jwala	1056	1889
ICPN-11-3	1437	
HMT - 1	1608	2650

In maize, maximum grain yield 5110 kg/ha was attained by NAH-2049. Ganga-11 was found to be the second best with a grain yield of 4790 kg/ha and Proagro-4643 with 4390 kg/ha. The entries had a variation of 19.2% in the season **(Table. 84).**

Chilli cv Samrudhi at Bangalore

Table. 84. Performance of maize hybrids and composite at Bangalore

Entries	Grain yield (kg/ha)
BIO-31006	3050
NAH 1144	4300
NAH 2049	5110
Ganga-11	4790
Cargill-900M	3930
Proagro-4643	4390

In respect of vegetable cowpea evaluated with chilli double cropping, PKB-4 genotype of cowpea was superior with a fresh pod yield of 13730 kg/ha during early *kharif*. The dry chilli yield was found to be 2071 kg/ha in association with this variety. However, during late *kha*irf, PKB-4 gave a relatively lower fresh pod yield of 4400 kg/ha compared to a maximum yield of 7230 kg/ha attained by APC-55270 variety. The lowest fresh pod yield of 2540 kg/ha was under early *kharif* was attained by AV-3 variety, while a minimum of 2920 kg/ha was attained by APC-489-91 under late *kharif* **(Table. 85).**

In a study to identify suitable genotypes of soybean in combination with chilli (Samruddhi variety), KB-280 variety was superior with a maximum yield of 1887 kg/ha, followed of AGS-334 with 1880 kg/ha. **(Table. 86).**

Table. 85. Identifying high yielding genotypes of vegetable cowpea that is suitable for raising as a first season crop in double cropping system

Genotypes	Fresh pod yield (kg/ha)		Dry chilli (kg/ha)
	Early *kharif*	Late *kharif*	
N.R.Pura local	12160	6360	1273
APC-711	11600	5320	1192
APC-489-91	3680	2920	1504
APC-552-70	7930	7230	1226
PV-3	11990	5260	972
AV-3	2540	5200	1504
PKB-4	13730	4400	2071
PKB-5	8630	7060	891
PKB-6	9790	6420	1273
Arka Samruddhi	11680	6940	1134
Arka garima	7610	6650	1273

Table. 86. Identification of appropriate genotypes of soybean different crops for intercropping and double cropping system in combination with chilli (Samruddhi)

Genotypes	Early *kharif*		Chilli yield (kg/ha)
	2005	Mean (3yrs)	2005
AGS-334	1880	1301	1696
MAUS-61	499	640	1736
MAUS-450	1716	1118	1218
KB-135	1373	1373	953
KB-226	1347	1347	1130
KB-280	1887	1887	1216

Among 16 genotypes of cowpea evaluated in combination with chilli during early *kharif* , IT-38956-1 was superior with a yield of 1800 kg/ha having maximum sustainability of 0.64 with mean yield of 1340 kg/ha in the last 3 years. V-16 variety of cowpea was superior in combination for chilli yield of 1620 kg/ha. However, V-16 variety gave a yield of 931 kg/ha **(Table. 87).**

In cowpea (short duration under late *kharif*), CP-14 was the best variety with a maximum seed yield of 1435 kg/ha.

Among 15 blackgram genotypes tested for late *kharif*, BDU-4, TAU-1 and LBG-625 were superior with a seed yield of 1330, 1328 and 1301 kg/ha. WBG-26 gave lowest yield of 387 kg/ha. BDU-4 was having a maximum sustainability of 0.53, while YAU-1 had 0.51 and LBG-625 had 0.48 in the last 3 years. In case of early *kharif* season, BDU-4 was superior with a yield of 1394 kg/ha. The chilli yield ranged from 1113 to 2296 kg/ha attained in combination with WBG-26 and JU-315 varieties respectively **(Table. 88).**

Among 26 different genotypes of greengram evaluated for green gram - chilli system 2KM-137 ranked first with a greengram yield of 1541 kg/ha, followed by chilli yield of 1853 kg/ha. TKG-1 was the second best greengram variety with a yield 1435 kg/ha, followed by a chilli yield of 1742 kg/ha. The lowest greengram yield of 409 kg/ha was attained by VI-6372 followed by a chilli yield by 808 kg/ha in the double cropping system under deep alfisols **(Table. 89).**

Table. 87. Identification of appropriate genotypes of cowpea under early and late *kharif* - Bangalore

Cowpea genotypes for early *kharif*					Cowpea genotypes for late *kharif*		
Genotypes	Cowpea Yield (kg/ha)			ChilliYield (kg/ha)	Genotypes	Cowpea Yield (kg/ha)	
	2005	Mean (3yrs)	SYI	2005		2005	Mean (2yrs)
C-152	1435	914	0.41	920	C-152	1105	1116
Cp-1	1577	1577		789	Cp-1	729	729
Cp-12	1544	1544		744	Cp-12	1211	1211
Cp-18	1416	1416		569	Cp-18	928	928
TC-201	827	475	0.16	811	KM-6	905	905
IT-38956-1	1800	1340	0.64	833	Konkon Sadabahar	653	561
V-16	931	931		1620	V-16	485	612

Table. 88. Identification of appropriate genotypes of different crops for intercropping and double cropping system (Evaluation of Blackgram Genotypes during late *kharif*)- Bangalore

Genotypes	Late *kharif*			Early *kharif*	
	Blackgram Seed Yield (kg/ha)		Chilli yield (kg/ha)	Blackgram	
	2005	Mean (3yrs)	SYI	2005	2005
BDU-2	1187	701	0.42	1760	1099
BDU-4	1330	851	0.53	1936	1394
K-3	1010	736	0.44	2186	1285
KU-315	528	532	0.29	2296	1235
LBG-625	1301	779	0.48	1900	1253
T-9	908	623	0.36	1506	463
TAU-1	1328	820	0.51	2223	728
TAU-104	1221	785	0.48	2153	1232
WBG-26	387	374	0.17	1113	530

Table. 89. Identification of appropriate genotypes of different crops for double cropping system (genotypes for greengram - cowpea system) - Bangalore

Greengeam genotypes	Greengram	Yield (kg/ha)	
		Yield (kg/ha)	Chilli
	2005	Mean (2yrs)	2005
Sel-4	1255	1255	3204
TM-7	1269	1269	1520
TM-99-37	1266	1266	1693
TKG-1	1435	1435	1742
VI-6372	409	409	808
2km-137	1541	1541	1853
2km-164	1283	1283	3422

In short duration greengram genotypes, 2KM-131 was the best variety with a seed yield of 1541 kg/ha. TKG-1 was the second best with a yield of 1435 kg/ha, while 2KM-164TM- 97-55 ranked third with yield of 1283 kg/ha. The lowest yield of 409 kg/ha was attained by VI-6372 **(Table. 90).**

Table. 90. Identification of appropriate blackgram genotypes for intercropping and double cropping systems – Bangalore

Genotypes	Yield (kg/ha)
2KM-137	1541
TM-7	1269
TKG-1	1435
VI-6372	409
2km-164	1283
TK-Local	805
NM-97	924
TM-99-37	1266
2km-101	967
SEL-4	1255
TKM-123	1117

In an initial rice evaluation trial, Doddabirenellu was the best variety with a grain yield 5833 kg/ha. Rasi variety was the second best with a yield of 5766 kg/ha, followed by Bhanaprava with 4706 kg/ha. **(Table. 91).**

Table. 91. Initial evaluation of rice varieties for drylands – Bangalore

Genotypes	Yield (kg/ha)
Bhanaprava	4706
Anjali	4246
Rasi	5766
Karidoddibatta	4703
Anekombinabattaa	1450
Doddabirenellu	5833

In an initial evaluation trial with 21 castor hybrids, CK-05-1HT-35 and CK-05-1HT-24 were the best with seed yields of 2833 and 2716 kg/ha respectively. These two entries also gave maximum oil yield of 1213 and 1038 kg/ha respectively. The lowest seed yield of 491 kg/ha and oil yield of 205 kg/ha were attained by CK-05-1HT-28 hybrid. The local checks Aruna and DCS-9 gave a seed yield of 1109 and 1099 kg/ha and oil yield of 458 and 444 kg/ha **(Table. 92).**

Table. 92. Initial evaluation of castor hybrids for yield and disease resistance under rainfed condition – Bangalore

Genotypes	Seed Yield (kg/ha)	Oil yield (kg/ha)
CK-05-IHT-19	2312	1017
CK-05-IHT-24	2716	1038
CK-05-IHT-28	491	205
CK-05-IHT-35	2833	1213
CK-05-IHT-36	2238	964
CK-05-IHT-37	2103	860
Aruna (LC)	1109	458
DCS – 9 (LC)	1099	444

3.5.3.2 Cropping systems

In a comparative evaluation of different green manure species tested in *kharif* followed by chilli, cowpea (KBC-2) was the best with a green manure bio-mass yield of 14200 kg/ha, followed by a dry chilli yield of 753 kg/ha. Horsegram (PHG-9) was the second best with a bio-mass yield of 12330 kg/ha followed by a maximum dry chilli yield of 1047 kg/ha in the study. **(Table. 93).**

3.5.3.3 Rain water management

The studies of double cropping forage crops followed by transplanted by chilli in rainfed environment along with protective irrigation during dry spells showed that Gaint pearlmillet (28,000 kg/ha) produced significantly higher yield over south-African maize (13,000 kg/ha) and sweet sorghum (12,000 kg/ha). Previous forage cropping had no significant effect on chilli yield. However green chilli yield was higher with sweet sorghum (3343 kg/ha) and lowest with Gaint pearlmillet (1842 kg/ha). Among the varieties of chilli Samurudh produced the higher yield (3605 kg/ha) compared Guntur-4 (1860 kg/ha). In respect of fertilizers recommended dose fertilizers produced 75% higher chilli yields compared to local variety **(Table. 94).**

Table. 93. Studies on *in situ* green manuring for efficient resource utilization and profitable crop production (comparative evaluation of different green manure crops)

Green manure species	Fingermillet			Chilli		
	Green Biomass yield (kg/ha)			Dry yield (kg/ha)		
	2005	Mean (4yrs)	SYI	2005	Mean (3yrs)	SYI
Sunhemp-1	12220	1210	0.30	1042	1139	
Dhaincha –1	7520	957	0.18	399	1234	0.13
Greengram (PS-16)	4540	8130	0.11	710	1418	0.19
Greengram (S-4)		810	0.11			
Blackgram (T-9)	5270	7000	0.06	643	1374	0.18
Cowpea (KBC-2)	14200	16920	0.53	753	1567	0.23
Horsegram (PHG-9)	12330	16000	0.53	1047	1759	0.29
Ricebean	5160	7570	0.09	757	1487	0.21
Veg. Cowpea (S-488)	5060	13130	0.35	915	1479	0.21
Cowhage	9020	8940	0.15	771	1176	0.12

Table. 94. Efficient utilization of farm pond water for intensive and profitable crop production - Bangalore

Treatments	Yield (kg/ha)	
	Green Forage	Green chilli
Early crops		
Fodder Maize	13000	3013
Fodder Jowar	12000	3343
Fodder bajra	28000	1842
Chilli varieties		
Samrudhi	17000	3605
G - 4	18000	1860
75% Rec.Fert.	17000	2550
100% Rec.Fert.	8000	2915

Among different treatments tested for controlling runoff, the lowest runoff 83 mm occurred under natural vegetation, while maximum runoff 486 mm occurred when sown along the slope **(Table. 95).**

Among different vegetative barriers tested in micro-watershed, khus live barrier was superior for attaining a maximum horse gram with a yield of 8967 kg/ha. This is followed by Nase live barrier with 8300 kg/ha, while the lowest yield of 6000 kg/ha was attained under no inter-terrace management practice **(Table. 96).**

3.5.3.4 Integrated nutrient management

To supply recommended N (FYM) + 60% NPK was superior with a soybean yield of 527 kg/ha. This had a maximum sustainability of 0.53 during the last 5 years. This was followed by FYM to supply recommended N with a yield of 444 kg/ha and a sustainability of 0.46 in the study **(Table. 97).**

In a study on fertilizer response, response to FYM and organic residues in groundnut at Bangalore, FYM @ 10 t/ha + 50% recommended NPK was superior with a pod yield of 4629 kg/ha under maize residue series. However, maize residue @ 5 t/ha + 100% recommended NPK was superior with a maximum yield 2794 kg/ha under maize residue series.

Table. 95. Estimation of runoff and soil loss under different crop management practices – Bangalore

Treatments	Runoff (mm)-2005
Sown across the slope with khus live barriers at 1.5 mt HI	313
Sown across the slope with paired row of Dhiancha live barriers 1.5mt HI	328
Sown across the slope with conservation furrows at 1.5mt HI	402
Sown across the slope	369
Sown along the slope	486
Natural vegetation (Control)	83

Table. 96. Integrated management of micro-watershed for sustainable dryland agriculture - Bangalore

Treatments	Horsegram yield (kg/ha)	
	2005	Mean (2yrs)
Khus live barrier	8967	4924
Nase Live barrier	8300	4625
No inter terrace Management practices (Control)	6000	3227

Table. 97. Fertility management of micro-watershed for sustainable productivity – Bangalore

Treatments	Soybean	Grain Yield (kg/ha)	
	2005	Mean (5yrs)	SYI
GLM to supply rec.N	166	356	0.29
FYM to supply rec.N	444	491	0.46
GLM to supply 50% of rec.N + 50% NPK	166	362	0.30
FYM to supply rec.N + 50%NPK	527	544	0.53
Rec.NPK	250	344	0.28
Control	194	165	0.05
GLM - Green leaf manure			

In case of fingermillet-fingermillet under mono crop sequence, application FYM @ 10/ha under FYM series or maize residue @ 5 t/ha under MR series together with 100 percent recommended NPK was superior with a maximum yield of 3156 kg/ha and 2339 kg/ha respectively in the season **(Table. 98).**

Among different organic and in organic treatments tested for fingermillet at Bangalore, application of 50% N by furrow placement of green leaf manure together with 50 percent NPK (inorganic) was superior with a maximum yield of 3633 kg/ha. This was followed by 50 percent N by spreading crop residue together with 50 percent NPK (Inorganic) with a yield of 3562 kg/ha. The lowest yield of 1056 kg/ha was attained by control in the season **(Table. 99).**

Table. 98. Response of FYM, organic residue and fertilizers – Bangalore

Treatments	Pod yield (kg/ha)					
	FYM series		SYI	Maize residue		SYI
	2005	Mean (6yrs)		2005	Mean (6yrs)	
Groundnut / fingermillet rotation						
Control	934	615	0.15	437	448	0.05
FYM 10t/ha or maize residue 5 t/ha	3501	2356	0.27	1254	910	0.07
FYM 10t/ha or maize residue 5 t/ha + 50% rec.NPK	4629	2656	0.34	2525	1748	0.31
FYM 10t/ha or maize residue 5 t/ha + 100% rec.NPK	4048	2537	0.31	2794	1988	0.38
100 % RDF (25:50:25 kg/ha NPK for groundnut, 50:50:25 kg/ha NPK for fingermillet)	2727	1552	0.08	2070	1765	0.31
Fingermillet / fingermillet monocrop						
Control	303	287	0.06	286	285	0.08
FYM 10t/ha or maize residue 5 t/ha	3046	2695	0.55	521	600	0.01
FYM 10t/ha or maize residue 5 t/ha +50% rec.NPK		3148	0.67	1817	1988	0.38
FYM 10t/ha or maize residue 5 t/ha + 100% rec.NPK	3156	3142	0.67	2339	2693	0.57
100 % RDF (50:50:25 kg/ha NPK for fingermillet)	1111	1688	0.30	1312	1938	0.36

Chilli cv Samrudhi at Bangalore

3.5.3.5 Tillage and nutrient management for resource conservation

In a tillage study for finger millet, conventional tillage and reduced tillage were at par with a yield of 3583 and 3531 kg/ha. They were superior to minimum tillage, which gave a yield of 3131 kg/ha in the season. Among fertilizer sources, application of 25% through FYM + 25% through glyricidia + 50% through urea was superior compared to 100% through organic source with a grain yhield of 3551 kg/ha. The tillage treatments had a sustainability in the range of 0.59 for minimum tillage and 0.75 for conventional tillage. Among fertilizer treatments, 25 percent N (FYM) + 25 percent N (Glyricidia) + 50 per cent N (urea) had a maximum sustainability of 0.76 in the last 4 years **(Table. 100).**

3.5.3.6 Alternate land use system and farming systems

Among 3 medicinal plant species evaluated under dryland condition, *Solanum viarum* was the best with a maximum yield of 5611 kg/ha in the season with mean yield of 4081 kg/ha in the last 6 years. *Hibiscus subdariffa* was the lowest yielder with a yield of 1006 kg/ha in the season with a mean yield of 792 kg/ha in the last 5 years **(Table. 101).**

Table. 99. Organic matter placement for carbon sequestration for dryland crop production – Bangalore

Treatments	Fingermillet grain yield (kg/ha)
50% N through GLM (Furrow placement) + 50% NPK	3633
50% N through GLM (Spread) + 50 % NPK	2927
50% N through FYM (Furrow placement) + 50% NPK	2962
50% N through FYM (Spread) + 50 % NPK	2222
50% N through crop residue (Furrow placement) + 50% NPK	2821
50% N through Crop residue (Spread) + 50 % NPK	3562
50% N (GLM+FYM+CR) Furrow placement + 50% NPK	3354
50% N (GLM+FYM+CR) Spread + 50 % NPK	3421
Recommended NPK	3350
Control	1056

GLM - Green leaf manure, FYM – Farm yard manure, CR- Crop residue

Table 100. Low till farming strategies and integrated plant nutrient supply for semi-arid tropics – Bangalore

Treatments	Fingermillet grain yield (kg/ha)		
	2005	Mean (4yrs)	SYI
Tillage			
Conventional tillage	3583	2987	0.75
Reduced tillage	3531	2797	0.70
Minimum Tillage	3131	2403	0.59
Fertility levels			
100% N through organic source (50%N (FYM)+ 50% (Glyricidia))	3229	2392	
50% N (organic) + 50% N (inorganic) (25% FYM + 25% Glyricidia+ 50% Urea)	3551	3000	0.76
100% N through inorganic source	3464	2775	0.69

Table 101. Evaluation of medicinal plant species suitable for their performance under dryland condition – Bangalore

Tree species	Yield (kg/ha)	Mean (6 yrs)
Hibiscus subdariffa (Pundi)	1006	834
Mucuna pruriens (Cowhage)	2542	2822
Solanum viarum (Alkaloid Solanum)	5611	3542

4. Operational Research Project

Dissemination of research information generated at the network centres to the clientele forms an integral part of the agricultural research. In this context, AICRPDA initiated this important activity through Operational Research Projects (ORPs) located at 8 Main centres viz., Ananthapur, Arjia, Bangalore, Ballowal Saunkhri,Hisar, Indore, Ranchi and Solapur. Initially the approach of ORPs was focused on a demonstration mode to solve the problems of the rainfed farming community in addition to the refinement of the technologies. Presently, at these centres , the programme are focus to farming systems mode for livelihood improvement of the rainfed farmers.

Objectives

- To understand the strength and weakness in the traditional system of dryland agriculture,
- To evaluate the performance of each component of dryland technology under the farmers management conditions,
- To provide feedback to the research stations for refinement of unsuitable recommendations,
- To achieve a first hand working experience in the development of micro-watersheds so that they may serve as a model for extension agencies,
- To identify operational and institutional constraints in the transfer of dryland technology, and
- To provide consultancy services to the extension agencies for transfer of dryland technology

4.1 Crops and Varieties

In rice based production system at Ranchi, Vandana variety was superior with a maximum grain yield (1859 kg/ha), followed by Birsa Vikas Dhan – 109 (1823 kg/ha). These varieties gave a net return of Rs.2890 and Rs.4345/ha respectively. The local gora gave a minimum yield of 1499 kg/ha and a net returns of Rs.1441/ha. In another trial on upland rice, Vandana was superior with a maximum grain yield of 1933 kg/ha and a net returns of Rs.3141/ha. However, Birsa Vikas Dhan – 109 gave 2nd best yield of 1895 kg/ha and a maximum net returns of Rs.4837/ha. Birsa niger – 1 recorded higher yield (383 kg/ha) net returns (Rs.1213/ha) and a BC ratio of 1.40. This was followed by Birsa niger – 2 with a yield of 327 kg/ha, net returns of Rs.597/ha having a BC ratio of 1.20. The local check gave a minimum yield of 228 kg/ha **(Table.102).**

Under Maize based production system, Navjot of maize was superior with a maximum grain yield of 330 kg/ha at Arjia, while PHEM-2 variety gave 280 kg/ha. In groundnut TAG – 24 gave highest pod yield (670 kg/ha), followed by JL – 24 (561 kg/ha). While the local variety gave a minimum yield of 397 kg/ha. Improved variety of horsegram AK-42 gave highest yield (350 kg/ha), followed by AK – 21 (280 kg/ha) and AK-1 (231 kg/ha), while local variety gave 198 kg/ha. At Ballowal Saunkhri, JH – 3459 of maize was superior (3056 kg/ha), followed by PMH – 2 with 2919 kg/ha. Parkash variety was the 3rd best with a yield of 2867 kg/ha, followed by Megha with 1887 kg/ha. The local variety gave a minimum yield of 1247 kg/ha. In groundnut, SG – 99 recorded highest yield of 1832 kg/ha, followed by M – 522 (1657) kg/ha and M – 548 variety (1621 kg/ha). In Wheat PBW – 527 gave a maximum yield of 1107 kg/ha, followed by PBW-175 with 1084 kg/ha. TL-1210 gave a yield of 857 kg/ha **(Table.103).**

At Bangalore, L – 5 variety of fingermillet registered highest grain yield (3127 kg/ha), followed by MR – 1 (3018 kg/ha), and HR – 911 (2630 kg/ha) and GPU – 28 (2508 kg/ha). The local variety gave a minimum yield of 1350 kg/ha in the trial. In a pigeonpea BRG – 1 gave a maximum grain yield of 912 kg/ha, followed by TTB – 7 with 805 kg/ha. HYD – 3C gave a yield of 765 kg/ha, while BRG – 2 gave a minimum yield of 548 kg/ha. Samruddhi variety of green chilli was superior with a yield of 6940 kg/ha compared to local variety with 4080 kg/ha under farmers' field conditions. In cowpea, IT – 38956 – 1 was superior with a maximum yield of 815 kg/ha. This was followed by KBC –2 (785 kg/ha) and KBC – 1 (535 kg/ha). Horsegram variety PHG – 9 gave a maximum yield of 738 kg/ha, while the local variety gave a minimum yield of 352 kg/ha. KBH – 1 was the 2nd best variety with a yield of 560 kg/ha.

At Hisar, HHB-67-2 was of pearlmillet gave a maximum grain yield of 1170 kg/ha. This was followed by HHB – 67 with 1050 kg/ha and HHB – 94 with 930 kg/ha. In mustard at Hisar, RH – 9304 gave a maximum yield of 760 kg/ha, while Laxmi variety gave a minimum yield of 660 kg/ha. RH – 30 was 2nd best with a yield of 690 kg/ha. In barley, BH – 393 was the best variety with maximum yield of 3110 kg/ha compared to BH - 87 with 2770 kg/ha and BH – 75 with 2540 kg/ha.

At Indore, JS – 9305 was superior with a maximum yield of 1390 kg/ha and gross returns of Rs.15290/ha. This was followed by NRC-7 with yield of 1316 kg/ha and gross returns of Rs.14476/ha. Samrat gave a minimum yield of 1058 kg/ha with a gross returns of Rs.11638/ha.

At Solapur, BSMR – 853 variety of pigeonpea was superior with a yield of 1155 kg/ha compared to local variety 780 kg/ha. The improved variety gave a yield increase of 48% compared to local variety. Shradha variety of pearlmilelt gave higher yield (1158 kg/ha), followed by Saburi (1060 kg/ha). Shradha variety gave a yield increase of 9% over Sauburi and 49% over local variety. The improved variety SS – 56 of sunflower was superior with a yield of 773 kg/ha compared to the local variety (638

kg/ha). The improved variety gave 21% yield increase over local variety in the trial. The MSFH – 17 hybrid of sunflower was highest yield of 1372 kg/ha, followed by Nimkar hybrid gave 1150 kg/ha.

Table 102. Influence of improved varieties on producltivity of upland rice and niger at Ranchi ORP center

Crop (No. of farmers)	Treatments	Yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	BCR
Upland rice (7)	Vandana	1859	7963	2890	1.57
	Birsa Vikash Dhan-109	1823	9618	4545	1.90
	Birsagora 102	1697	7334	2261	1.45
	Birsa dhan – 108	1616	6995	1922	1.38
	Local gora ©	1499	6514	1441	1.28
Upland rice (5)	Birsagora 102	1691	7268	2195	1.43
	Vandana	1933	8214	3141	1.62
	Birsa dhan-108	1618	6997	1924	1.38
	Birsa Vikash Dhan-109	1895	9910	4837	1.95
Niger (10)	Local check	228	2508	-492	0.84
	Birsa niger-1	383	4213	1213	1.40
	Birsa niger-2	327	3597	597	1.20

Table. 103. Effect of improved cultivars on productivity of different crops at ORP centers

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)
Arjia	Maize (4)	Local	147
		Navjot	330
		PHEM-2	280
	Groundnut	Local	397
		JL-24	561
		TAG-24	670
Arjia	Horsegram	Local	198
		AK-1	231
		AK-21	280
		AK-42	350
B.Saunkhri	Maize	Local	1247
		Megha	1887
		Parkash	2867
		JH-3459	3056
		PMH 2	2919
	Groundnut	SG-99	1832
		M522	1657
		M548	1621
	Wheat	PBW 175	1084
		PBW 527	1107
		PBW 343	934
		TL 1210	857
	Fingermillet	Local	1350
		L-5	3127
		MR-1	3018
		GPU-28	2508
		HR-911	2630
		GPU-26	1820
		GPU-48	1935

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)
	Pigeonpea	TTB-7	805
		Hyd-3c	765
		BRG-1	912
		BRG-2	548
	Chilli	Local	4080
		Samruddhi	6940
	Cowpea	TVX-94402E	495
		IT-38956-1	815
		KBC-1	535
		KBC-2	785
	Horsegram	Local	352
		PHG-9	738
		KBH-1	560
	Fodder crops	Maize (South African Tall)	28600
		Pearl millet (Gaint bajra)	33850
		Sorghum (SSV-74)	16300
Hisar	Pearlmillet	HHB-67	1050
		HHB 67-2	1170
		HHB –94	930
Hisar	Mustard	RH – 30	690
		RH – 9304	760
		Laxmi	660
	Barley	BH – 75	2540
		BH – 87	2770
		BH – 393	3110
Indore	Soybean	Samrat	1058
		JS-335	1272
		NRC-7	1316
		JS-9305	1390
Solapur	Pigeonpea	Local	780
		BSMR-853	1155
	Pearlmillet	Local	776
		Shradha	1158
		Saburi	1060
	Sunflower (Variety)	Local	638
		SS-56	773
	Sunflower (Hybrid)	MSFH-17	1372
		Nimkar	1150
	Maize	Local	1520
		MPQ-13	2154
	Sorghum	Mouli	845
		Phule Yashoda	1719
		M 35-1	1091

4.2 Cropping Systems

At Ranchi, Pigeonpea + rice (1:3) registered highest pigeonpea equivalent yield of 749 kg/ha compared to sole pigeonpea with 556 kg/ha and sole rice with 300 kg/ha. This also gave a maximum net returns of Rs.5035/ha with a BC ratio of 1.81. While the sole pigeonpea gave a net returns of Rs.3540/ ha with a BC ratio of 1.73. Sole rice with a net returns of Rs.1150 /ha with a BC ratio of 1.32. In pigeonpea + groundnut intercropping (1:2) a maximum pigeonpea equivalent yield of 1587 kg/ha was attained compared to sole groundnut (1291 kg/ha) sole pigeonpea (491 kg/ha). The intercropping system gave a maximum net returns of Rs.15405/ha with a BC ratio of 2.83, while sole groundnut gave Rs.11865/ha with a BC ratio of

Pigeonpea + Upland rice at Ranchi (ORP)

2.58. Intercropping of pigeonpea + maize was found to be the best with a maximum pigeonpea equivalent yield (1049 kg/ha) compared to sole maize (777 kg/ha) and sole pigeonpea (500 kg/ha). The system gave a maximum net returns of Rs.9235/ha with a BC ratio of 2.77. Pigeonpea + okra inter cropping recorded a maximum pigeonpea equivalent yield of 595 kg/ha together with a net returns of Rs.3425/ha and a BC ratio of 1.62. Sowing on 15th November was best to attain with a maximum yield of pea (1640 kg/ha), followed by 30th October (1545 kg/ha) and 30th November (1484 kg/ha) **(Table.104).**

Table.104. Effect of cropping systems on productivity, gross and net returns at ORP centers

Center	Crop (No. of farmers)	Treatments	Pigeonpea equivalent yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	BCR
Ranchi	Pigeonpea + Rice (1:3) (7)	Pigeonpea sole	556	8340	3540	1.73
		Rice sole	300	4750	1150	1.32
		Pigeonpea + rice (1:3)	749	11235	5035	1.81
Ranchi	Pigeonpea+ Groundnut (1:2) (7)	Pigeonpea sole	491	7365	2565	1.53
		Groundnut sole	1291	19365	11865	2.58
		Pigeonpea + groundnut (1:2)	1587	23805	15405	2.83
Ranchi	Pigeonpea+ Maize (1:1) (10)	Sole pigeonpea	500	7791	2991	1.62
		Maize sole	777	11655	7355	2.71
		Pigeonpea + maize	1049	15737	9235	2.77
Ranchi	Pigeonpea + okra (6)	Sole pigeonpea	495	7425	2625	1.55
		Sole okra	390	5850	1850	1.46
		Pigeonpea + okra (1:2)	595	8925	3425	1.62
Bangalore	Finger millet & other crops	Farmer practice (Finger millet + akkadi)	—	11662	2455	1.27
		Finger millet + pigeonpea (10:2)	—	4422	2124	1.93
		Finger millet + soybean (4:1)	—	3127	724	1.30
		Sole field bean	—	2496	774	1.45
		Maize + cowpea (green fodder) (3:1)	—	5280	2830	2.13
		Pigeonpea + cowpea (1:1)		3375	1170	1.53
Bangalore	Fingermillet & other crops	Finger millet + pigeonpea	2260+718	24009	12319	2.05
		Finger millet + soybean	2315+150	16692	4677	1.39
		Finger millet + sorghum fodder (Farmers practice)	1470+1350	10538	2331	1.28
	Groundnut & pigeonpea	Groundnut + pigeonpea	625+738	18969	3599	1.23
	Pigeonpea & cowpea	Pigeonpea + cowpea	835 + 340	15275	4254	1.39
Anantapur	Groundnut & pigeonpea	Groundnut + pigeonpea (early sowing)	848 (GN)	13833	6966	1.88
		Groundnut + pigeonpea (normal sowing)	926 (GN)	15482	8137	2.11
Anantapur	Groundnut	Farmers practice (Bold seed)	836		4550	1.58
		Small seed	848		5216	1.76
Solapur	Pigeonpea & cluster bean	Sole pigeonpea	1091	16911		1.82
		Pigeonpea+cluster bean (1:2)	976+1400	24315		2.26
Solapur	Castor & cluster bean	Sole castor	400	4800		0.52
		Castor + cluster bean (1:2)	355+1200	13860		1.35

At Arjia, maize + blackgram (2:2 ratio) was superior with a yield of maize 1760 kg/ha, followed by maize - blackgram strip cropping in 10:20 ratio with 1324 kg/ha. Maize – blackgram rotation gave 1226 kg/ha. Maize + black gram in 1:1 ratio was superior compared to maize + blackgram and sole maize at Ballowal Saunkhri. The system gave a maize equivalent yield of 3428 kg/ha compared to sole maize yield of 3060 kg/ha. Maize + greengram system gave a maize equivalent yield of 3161 kg/ha.

The intercropping of wheat and raya crops at Ballowal saunkhri, in 10:1 ratio gave highest wheat equivalent yield of 1448 kg/ha. While, sole wheat gave a yield of 1211 kg/ha in the trial conducted at 3 farmers' fields **(Table 105).**

Pearlmillet + Clusterbean at Hisar (ORP)

Table 105. Effect of improved crops and cropping systems under ORP

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)	Gross returns (Rs/ha)
Hisar	Pearlmillet, cluster bean & green gram	Sole Pearl millet (PM) 45 cm	690	4140
		Pearl millet + cluster bean (8:4) 30 cm	520+ 190	5780
		Sole cluster bean 45 cm	490	6860
		PM + green gram (8:4) 30 cm	540 + 180	6840
		Sole green gram 45 cm	540	10800
	Chickpea & other crops (2)	Chickpea (paired row 30:60)	600	12000
		Chickpea (PR) + oat fodder (70 DAS)	560+3520	12960
		Chickpea (PR) + Chinese cabbage fodder (70 DAS)	580+4730	13965
		Chickpea (PR) + *B.napus* fodder (70 DAS)	580+3770	13485
		Fallow – *rabi* sorghum	1437	18081
Ranchi	Wheat (5)	Farmers Practice	1021	
		Sowing behind country plough	991	
		Sowing with seed drill	790	
Arjia	Maize & black gram	Sole maize	392	
		Maize-black gram strip cropping (10:20) (3)	455	
		Maize + black gram (2:2)	736	
B.Saunkhri	Maize + blackgram/ greengram (maize equivalent yield)	Sole maize	3060	
		Maize + blackgram (1:1)	3428	
		Maize + green gram (1:1)	3161	
	B.Saunkhri	Sole wheat	1211	
		Wheat + raya (10:1)	1448	

In Bangalore, ORP maize + cowpea (green fodder) in 3:1 ratio gave net returns of Rs.2830/ha with a BC ratio of 3.13. This was followed by finger millet + pigeonpea in 10:2 ratio with a net returns of Rs.2124/ha and a BC ratio of 2.93. The farmers practice of finger millet + akkadi gave a minimum BC ratio of 2.27. In an assessment of different intercropping systems at Bangalore under farmers' field conditions, finger millet + pigeonpea recorded net returns of Rs.12319/ha with a BC ratio of 3.05. This was followed by finger millet + soybean with Rs.4677/ha and BC ratio of 2.39. Finger millet + sorghum (fodder) provided a net returns of Rs.2331/ha and BC ratio of 2.28. In a pigeonpea based intercropping trial, pigeonpea + cowpea gave highest net returns of Rs.4254/ha having BC ratio of 2.39.

At Hisar, a maximum net returns of Rs.10800/ha was attained with sole greengram in 45 cm spacing, followed by pearl millet + greengram in 8:4 ratio with 30 cm spacing (Rs.6840/ha). Chickpea (in paired rows of 30 and 60 cm) based intercropping systems, chickpea + Chinese cabbage fodder (70 DAS) gave highest net returns of Rs.13965/ha, followed chickpea + B. Napus fodder (70 DAS) (Rs.13485/ha). The sole chickpea gave a minimum net returns of Rs.12000/ha in the trial.

The normal sowing of groundnut + pigeonpea was superior compared to early sowing at Anantapur. The normal sowing gave a higher net returns of Rs.8137/ha with a BC ratio of 2.11. Compared to this, the early sowing of crops provided a net returns of Rs.6966/ha and a BC ratio of 1.88.

At Solapur, a new sorghum fodder variety Phule Amruta (RSSV – 9) gave a 2 mean yield of 44000 kg/ha under irrigated condition. The sowing done on 6th July gave 41500 kg/ha, while the sowing done on 24th July gave 46500 kg/ha of fodder yield. In a trial on forage production with irrigation, maize – berseem system gave a mean green fodder yield of 54000 kg/ha of maize in *kharif* and 58300 kg/ha of berseem in *rabi* season respectively.

In sunflower – berseem cropping system, a mean grain yield of 1603 kg/ha of sunflower and fodder yield of 70750 kg/ha of berseem were attained. The sowing of sunflower done on 11th August and berseem on 10th November was found to be optimum.

In sunflower + pigeonpea (2:1), a maximum gross returns of Rs.20422/ha were attained together with a land equivalent ratio of 1.40. The sole pigeonpea gave Rs.18104/ha, while the sole sunflower gave Rs.12350/ha.

Pigeonpea + clusterbean gave a highest gross monetary returns of Rs.24315/ha with a BC ratio of 2.26. The sole pigeonpea gave Rs.16911/ha with a BC ratio of 1.82, while sole cluster bean gave Rs.10024/ha.

Castor + cluster bean (1:2 ratio) in one farmers' field, system gave a gross returns of Rs.13860/ha with a BC ratio of 1.35. Apart sole castor gave Rs.4800/ha with a BC ratio of 0.52.

The sequence cropping of greengram – sorghum gave a gross monetary returns of Rs.20824/ha compared to sole *rabi* sorghum with Rs.18082/ha. A higher soil N of 220 kg/ha was observed under greengram – sorghum sequence compared to 198 kg/ha under fallow – sorghum sequence after harvest of *rabi* sorghum.

4.3. Rainwater Management

At Arjia, One supplemental irrigation at 55 DAS recorded highest (1225 kg/ha) for maize + blackgram as aginst the control (485 kg/ha). Similarly, one supplemental irrigation at 45 DAS was superior in groundnut + sesame (6:2) under 2 farmers fields with 1402 kg/ha of maize equivalent yield. Control gave a yield (888 kg/ha). Deep tillage + 100% recommended fertilizer through FYM and inorganic fertilizer was superior was maize yield (1814 kg/ha), followed by deep tillage + 50% recommended fertilizer in through FYM and inorganic source (1570 kg/ha). The farmers' practice of shallow tillage gave minimum yield of 1138 kg/ha.

At Ballowal Saunkhri, chiseling + mulching gave highest grain yield of 3183 kg/ha, followed by only mulching (2617 kg/ha) and only chiseling (2583 kg/ha), while the farmers' practice gave lowest yield of 1691 kg/ha.

At Bangalore, finger millet + pigeonpea (10:2) ratio was superior with maximum gross returns of Rs.20330/ha and a BC ratio of 1.78. The contour cultivation and sowing of finger millet was the 2nd best with gross returns of Rs.14162/ha and a BC ratio of 1.25. However, finger millet + sorghum in 10:1 ratio gave a higher BC ratio of 1.48 with a gross returns of Rs.12258/ha. The control of sowing along the slope of finger millet crop gave a minimum gross returns of Rs.9170/ha with BC ratio of 1.16.

At Ranchi, minimal irrigation for pea enhanced the profitability (Rs. 8257/ha), followed by wheat (Rs. 3887/ha).

Application of 10 mm water from pond during dry spell of more than 10 days gave a higher pod yield of 1038 kg/ha compared to a control yield of 620 kg/ha at Anantapur.

Application of 2 protective irrigations at 35 and 65 DAS for sorghum gave higher yield of 1425 kg/ha compared to control (1300 kg/ha). The *rabi* sorghum yield increased by 33% due to protective irrigation over no irrigation. At Solapur, ridges and furrows in *rabi* sorghum was the best practice with a maximum grain yield of 1139 kg/ha. This was followed by compartmental bunds with a yield of 923 kg/ha. The farmers' practice of 2 harrowings gave a minimum yield of 791 kg/ha. Application of 2 protective irrigations gave highest yield of 1091 kg/ha as against a mean yield of 680 kg/ha without irrigation (680 kg/ha). The protective irrigation gave a yield increase of 60% over no irrigation in the trial **(Tables 106 & 107).**

Table 106. Effect of rain water management practices on crop productivity, gross and net returns at ORP centers

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	BCR
Ranchi	Wheat (20)	Minimal irrigation for wheat	1613	9063	3883	1.75
	Pea	Minimal irrigation	1465	14802	8257	2.25
	Mustard	Minimal irrigation	327	3790	740	1.24
Banga-lore	Fingermillet	Cultivation & sowing along the slope	1450	9170		1.16
		Finger millet + sorghum (10:1)	1900	12258		1.48
		Contour cultivation & sowing	2315			1.25
		Finger millet + pigeonpea (10:2)	2550+350	20330		1.78

Table 107. Effect of rain water management practices on crop productivity at ORP centers

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)
Ranchi	Linseed (10)	Interculturing at 25 DAS	255
		Interculturing	228
	Linseed	Dust mulching (Farmers practice)	211
		Mulching with Ipomea leaves	266
		Dust mulching + mulching with Ipomea leaves	294
Arjia	Maize + blackgram (2)	Control	485
		Supplemental irrigation	1225
	Groundnut + sesame (2)	Control	888
		Supplemental irrigation	1402
	Maize (3)	Shallow tillage + Farmers practice	130
		Deep tillage + RAS + 100% recommended FYM and inorganic fertilizer	337
		Deep tillage + RAS + 50% recommended FYM & inorganic fertilizer	227
		Deep tillage + RAS + Farmers practice	173
B.Saunkhri	Maize (3)	Farmers Practice	1691
		Chiseling	2583
		Mulching	2617
		Chiseling + mulching	3183
Anantapur	Groundnut (2)	Control	620
		Application of 10 mm water from pond during dry spell (>10 days) depending on availability of harvested water	1038
Solapur	Sorghum (3)	With irrigation at 35 & 65 DAS	1725
		Without irrigation	1300
	Sorghum (6)	Farmers practice (two harrowings)	791
		Compartmental Bund	923
		Ridges & furrows	1139
	Chickpea	Two protective irrigations	1091
		No irrigation	680

4.4 Integrated Nutrient Management

At Ranchi, an application of 20 kg N + 20 kg P/ha (basal) gave a maximum mean yield (1279 kg/ha), net returns (Rs.1946/ha) and BC ratio (1.56). This was significantly higher compared to farmers practice of 20 kg N/ha at 30 DAS (428 kg/ha). Application of only N @ 20 kg/ha (basal) gave a significantly lower yield of 852 kg/ha. In an application of 40 kg K/ha gave highest net returns of Rs. 2996/ha and BC ratio of 1.57 in rice **(Table 108).**

At Arjia, application of 50% N (organic) + 50% N (inorganic) gave a yield of 313 kg/ha compared to 100% N inorganic (240 kg/ha) for maize under maize + blackgram system. This gave 30.4% yield increase over application of entire fertilizer through inorganic source **(Table 109).**

At Ballowal Saunkhri, application of 50% N (FYM) + 50% N (inorganic) gave a significantly maize yield of 3805 kg/ha compared to 100% N (organic) with 2111 kg/ha. Application of 100% N (inorganic) was the 2nd best with 3511 kg/ha of grain yield. Significantly higher maize yield of 1857 kg/ha was attained with soil test based NPK dose compared to farmers practice with 817 kg/ha. Application of 100 percent recommended NPK was the 2nd best with a yield of 1817 kg/ha. In a trial on phosphorus management in 5 farmers' fields, application of 40 kg P/ha to maize gave a yield of 2580 kg/ha while application of 80 kg P/ha gave a yield of 2671 kg/ha.

At Bangalore, application of 50% NPK (FYM) + 50% NPK (inorganic) was superior with a grain yield of 2470 kg/ha compared to farmers practice with 1530 kg/ha. In an evaluation of rhizobia and phosphorous solubilizing bacteria for groundnut 'TMV - 2' and pigeonpea 'TTB - 7' varieties, application of bio-fertilizer gave a superior yield of 695 kg/ha of groundnut and 790 kg/ha of pigeonpea compared to the control plot. The yield increase was of the order 13.6% in groundnut and 14.5% in pigeonpea.

Application of 40 kg N/ha recorded maximum yield of pearlmillet (930 kg/ha) at Hisar. While application of 20 kg N/ha + azotobacter gave 840 kg/ha and with FYM @ 4 t/ha + azotobacter gave 790 kg/ha. The control gave a minimum yield of 660 kg/ha. In a trial on mustard, a maximum yield of 980 kg/ha was attained with application of 40 kg N/ha.

Table 108. Integrated nutrient management for crops at Ranchi

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	BCR
Rice production system						
Ranchi	Upland rice (8)	Farmers practice (20 kg N/ha at 30 DAS)	428	1831	-1169	-1.39
		20 kg N/ha+ 20 kg P/ha (basal)	1279	5446	1946	1.56
		20 kg N/ha (basal)	852	3565	565	1.19
	Upland rice (8)	Control	1333	5621	821	1.17
		80 kg K/ha	2045	8371	2871	1.52
		40 kg K/ha	2015	8246	2996	1.57
		20 kg K/ha	1727	7050	1977	1.40

Table 109. Influence of integrated nutrient management of different crops at different ORP centers

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)
Maize production system			
Arjia	Maize+ black gram (3)	Control	240
		50% N (organic) + 50% N (inorganic)	313
Arjia	Maize (5)	50% N through organic and 50% N through chemical fertilizer	313
		100% N through inorganic fertilizer	240
B.Saunkhri	Maize (2)	100% organic N	2111
		50% organic N + 50% N (inorganic)	3805
		100 % N (inorganic)	3511
	Maize (2)	Farmers practice	817
		Recommended N	1161
		Recommended NP	1439
		Recommended NPK	1817
		Soil test based NPK	1857
B.Saunkhri	Maize (5)	Control	1810
		20 kg P/ha	2188
		40 kg P/ha	2580
		80 kg P/ha	2671
Bangalore	Finger millet	Farmers practice	1530
		50% NPK + 50% N (FYM)	2470
		100% NPK	2245
	Groundnut	Groundnut Rhizobia + PSB	695
		Control	612
	Pigeonpea	Pigeonpea Rhizobia + PSB	920
		Control	790
Hisar	Pearlmillet (5)	Control	660
		20 kg N/ha + Azotobacter	840
		20 kg N/ha	770
		40 kg N/ha	930
		FYM 4t/ha + Azotobacter	790
	Mustard (5)	Control	620
		20 kg N/ha	810
		20 kg N/ha + Azotobacter	850
		40 kg N/ha	980
		FYM 4t/ha + Azotobacter	910

At Anantapur, soil test based fertilizer application gave a pod yield of 1050 kg/ha compared to farmers practice of DAP @ 50 kg/ha with a groundnut pod yield of 888 kg/ha. The improved fertilizer dose gave higher net returns of Rs.7765/ha with BC ratio of 2.01, while the farmers' practice gave Rs.5530/ha with a BC ratio of 1.75.

Application of 100% recommended dose (50 kg N + 60 kg P/ha) + sulphur @ 20 kg/ha was superior for soybean. This gave a maximum yield of soybean (1132 kg/ha) net returns (Rs.6373/ha) and BC ratio (1.94). While 100 percent recommended dose gave a yield of 1018 kg/ha with a net returns

of Rs.5298/ha and BC ratio of 1.81. The farmers practice of DAP @ 50 kg/ha gave the lowest yield of 678/ha with a net returns of Rs.2262/ha having a BC ratio of 1.40. In a crop residue management trial with NADEP compost for soybean under 5 farmers' fields, the recommended dose of 30 kg N+60 kg P/ha gave a yield increase of 29.6% over farmers practice. The treatment gave a mean yield of 954 kg/ha compared to farmers practice with 736 kg/ha. The farmers practice+compost @ 5 t/ha gave a yield of 864 kg/ha. Significantly higher yield of soybean (1143 kg/ha) with a yield increase of 46.5% over farmers practice was attained with an application of 100% recommended fertilizer (30 kg N + 60 kg P/ha) together with zinc sulphate @ 25 kg/ha. This gave maximum net returns of Rs.6423/ha with a BC ratio of 1.91. Application of 100% RDF + foliar application of 0.05% of zinc sulphate+0.02% of boron at 30 and 45 DAS gave a significantly higher grain yield of 1162 kg/ha and a yield increase of 52.5% over farmers' practice. This gave maximum net returns of Rs.6157/ha with a BC ratio of 1.83. The farmers practice of DAP @ 50 kg/ha gave the lowest yield of 762 kg/ha with a net returns of Rs.3268/ha and BC ratio of 1.58 in the trial.

At Indore, application of 80 kg P/ha as basal (single super phosphate) was superior with a significantly higher grain yield of 1561 kg/ha and a yield increase of 68.6%. This was followed by 40 kg P/ha as basal with a yield of 1248 kg/ha and a yield increase of 34.8%.

At Solapur, application of 50 kg N + 25 kg P/ha gave a superior yield of (1254 kg/ha) and returns (Rs.16331/ha) compared to control (825 kg/ha) with gross returns of Rs.10445/ha. The fertilized plot provided a soil N of 198 kg/ha and soil P of 14.7 kg/ha compared to a control of 175 kg/ha of N and 12.2 kg/ha of P after harvest of *rabi* sorghum. In a trial on pearl millet under 4 farmers' fields at Solapur, application of 50 kg N + 25 kg P + 25 kg K/ha was superior with a mean yield of 1421 kg/ha and a yield increase of 15%. The treatment without potassium gave a mean yield of 1238 kg/ha **(Table 110)**.

4.5. Energy Management

At Ranchi, weeding by grubber gave highest yield of 1848 kg/ha with a BC ratio of 1.35 and weeding efficiency of 72%. While in upland rice, weeding by dryland weeder gave an at par yield (1714 kg/ha), BC ratio (1.23) and weeding efficiency (65%). Ploughing with mould board plough together with a ploughing with Birsa ridger plough gave significantly highest grain yield of rice 1428 kg/ha. The seed bed preparation with 2 ploughings with Birsa ridger plough was the 2nd best with a yield of 1295 kg/ha. It is observed that the width for furrow, the depth of furrow, the effective field capacity and speed of operation were higher for mould board plough and Birsa ridger plough compared to the farmers practice of using country plough **(Table 111 & 112).**

Table 110. Effect of integrated nutrient management practices on productivity of different crops in ORP centers

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	BCR
Anantapur	Groundnut (9)	Farmers practice (50 kg/ha DAP)	888	12875	5530	1.75
		Soil test based fertilizer application	1050	15446	7765	2.01
Indore	Soybean (5)	Farmers practice (50 kg/ha DAP)	678	7864	2262	1.40
		RDF (50 kg N+ 60 kg P/ha)	1018	11798	5298	1.81
		RDF + 20 kg Sulphur /ha	1132	13123	6373	1.94
	Soybean (5)	Farmers practice (50 kg/ha DAP)	926	10749	5149	1.91
		Recommended dose (50 kg N and 60 kg P/ha)	1306	15125	8625	2.32
		50% RDF + 4 t FYM/ha	1264	14660	7760	2.12
		50% RDF + Rhizobium culture + PSM	1038	12049	6049	2.00
	Soybean (5)	Farmers practice (50 kg/ha DAP)	780	8441	2841	1.50
		Recommended dose (50 kg N and 60 kg P/ha)	998	11577	5077	1.78
		50 % RDF + 25 kg ZnSO4/ha (as basal)	770	8936	2786	1.45
		RDF + 25 kg ZnSO4/ha (basal)	1143	13473	6423	1.91
Indore	Soybean (5)	Farmers practice (50 kg/ha DAP)	762	8868	3268	1.58
		RDF (50 kg N+ 60 kg P/ha)	1018	11822	5322	1.81
		50 kg DAP/ha + foliar application of 0.02% at 30 and 45 DAS	786	9149	2649	1.55
		50 % of RDF + foliar application of 0.02% at 30 and 45 DAS	1080	12626	5826	1.85
		RDF + foliar application of 0.05 % of ZnSO4 & 0.02 % of Boron at 30 & 45 DAS	1162	13501	6157	1.83

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	BCR
Solapur	Sorghum (5)	Without fertilizer	825	10445		
		With fertilizer (50 kg N + 25 kg P/ha)	1254	16331		
	Lucerne (2)	Perennial lucerne (RL-88) (green fodder)	60300			
	Pearlmillet (4)	50 kg N+ 25 kg P + 25 kg K	1421			
		50 kg N+ 25 kg P (no K)	1238			

Table 111. Effect of energy management practices on productivity, gross and net returns of crops at ORP centers of Ranchi and Anantapur

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	BCR
Ranchi	Upland rice (5)	Farmers Practice (weeding by khurpi at 30 DAS)	2046	8617	3544	1.70
		Weeding by dryland grubber at 30 DAS	1919	8163	3613	1.79
		Pre-emergence application of Butachlor @ 1.5 kg a.i./ha	1899	8011	5161	1.81
Anantapur	Ground-nut (8)	Farmers practice	833	13493	6148	1.83
		Mechanical seed drill	851	13884	6614	1.91
	Groundnut (2)	Farmers method	985			
		Mechanization	1022			

Table 112. Effect of energy management practices on productivity of crops in ORP centers

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)
Ranchi	Upland rice (5)	Farmers practice (two ploughings with country plough	1239
		One ploughing with mould board plough + one plough with Birsa ridger plough	1428
		Two ploughings with Birsa ridger plough	1295
	Wheat (5)	Farmers practice	1021
		Sowing behind country plough	991
		Sowing with seed drill (animal drawn pora)	790
Arjia	Maize (2)	Cultivator	187
		Rotavator	310
		Cultivator + blade harrowing after sowing	265
		Cultivator + Atrazine	220
B.Saunkhri	Wheat (3)	Wooden plough	1009
		Seed-cum-fertilizer drill	1188
	Chickpea (3)	Wooden plough	316
		Seed-cum-fertilizer drill	444

At Arjia, rotavator gave 65.8 percent higher grain yield in maize as compared to the farmers' fields using cultivator (187 kg/ha). The cultivator+blade harrowing after sowing was the 2nd best with a yield of 265 kg/ha and yield increase of 41.7 percent over farmers practice.

In wheat at Ballowal Saunkhri, the seed–cum–fertilizer drill gave the yield of 1188 kg/ha compared to wooden plough with 1009 kg/ha. The seed-cum-fertilizer drill gave higher emergence count per meter row length of 39.2 percent compared to wooden plough with 36.5 percent. Similarly, for chickpea use of seed–cum–fertilizer drill and wooden plough gave higher grain yield of 444 kg/ha compared to wooden plough with 316 kg/ha. There was a yield increase of 40.5 percent with the mechanical seed drill compared to the manual seed drill.

At Anantapur, the tractor drawn mechanical seed drill gave a relatively higher pod yield of 851 kg/ha compared to farmers' practice with bullock – drawn seed drill (833 kg/ha). The improved seed drill gave a higher gross returns of Rs.6614/ha

with a BC ratio of 1.91 compared to the farmers practice with Rs.6148/ha and BC ratio of 1.83 under 8 farmers' fields.

4.6. Package of Practices

The improved bio-diverse farming system gave a higher maize yield of 1252 kg/ha compared to traditional cropping system with a yield of 388 kg/ha at Arjia.

In wheat at Ballowal Saunkhri, the recommended practices gave the highest grain yield of (1700 kg/ha), followed by 22.5 cm row spacing (1500 kg/ha) and farmers' practice (710 kg/ha). In barley, complete package of practices gave a maximum yield of 1000 kg/ha, followed by 867 kg/ha without application of fertilizer. The farmers' practice of untreated seed and no fertilizer gave a minimum yield of 587 kg/ha in the trial. The complete package of practices in raya gave highest yield of 411 kg/ha, followed by the recommended package with local variety (349 kg/ha). The farmers' practice gave a minimum yield of 189 kg/ha. In taramira, a maximum yield of 254 kg/ha was attained by using the complete package of practices. This was followed by a yield of 207 kg/ha with the recommended package with either local variety or without fertilizer. The farmers 'practice gave lowest yield of 143 kg/ha. In a testing of improved and farmers practices for maize (11 farmers' fields), groundnut (6), fodder pearl millet (5), wheat (9), barley (5), chickpea (6), raya (2) and taramira (2) under farmers field conditions at Ballowal Saunkhri, the improved practice was superior for all the crops with a higher yield compared to farmers practice. The improved practice gave a yield of 2242 kg/ha of maize, 1509 kg/ha of groundnut, 33980 kg/ha of fodder pearl millet, 1161 kg/ha of wheat, 643 kg/ha of barley, 333 kg/ha of chickpea, 645 kg/ha of raya and 192 kg/ha of taramira.

At Arjia, a yield increase of 74.4% in sesame, 64.5% in blackgram 46.2% in greengram and 88.3% in cluster bean was attained compared to farmers practice for respective crops.

At Arjia, the improved practices in groundnut + sesame in intercropping system gave highest maize equivalent yield (1294 kg/ha) and also groundnut equivalent yield (1258 kg/ha). Compared to this, the farmers' practice gave a maize equivalent yield of 889 kg/ha and also groundnut equivalent yield of 963 kg/ha.

At Arjia, the improved practice gave a yield increase of 44 percent in greengram, 50 percent in mothbean, 39 percent in clusterbean and 35 percent in sesame over farmers' practice. In chickpea, the complete package of practices gave highest yield of 760 kg/ha. The reduction in yield compared to complete package was 65 percent in control, 19 percent without endosulfan, 10 percent without rhizobium culture, 27 percent without fertilizer and 17 percent without interculture operations.

At Anantapur, highest pod yield (848 kg/ha) was attained with small seed of groundnut compared to farmers practice (bold seed)(836 kg/ha). The use of small seed gave a higher net returns of Rs.5216/ha with BC ratio of 1.76 compared to farmers practice with Rs.4550/ha having BC ratio of 1.58. The improved practice of groundnut + pigeonpea was superior with a yield of 1114 and 57 kg/ha of corresponding crops compared to farmers practice with 926 and 53 kg/ha respectively. The improved practice gave a net returns of Rs.11022/ha compared to farmers practice (Rs.7805/ha).

At Solapur, the improved practice gave a yield of 1524 kg/ha of sorghum, 2195 kg/ha of maize, 838 kg/ha of chickpea, 779 kg/ha of sunflower and 1115 kg/ha of safflower compared to 748, 1592, 573, 510, and 647 kg/ha of the respective crops under farmers' practice **(Table 113 & 114).**

Table 113. Effect of package of practices on productivity, gross and net returns of crops at ORP at Anantapur

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	BCR
Anantapur	Groundnut	Farmers practice (bold seed)	836	12445	4550	1.58
	(5)	Small seed	848	12051	5216	1.76
	Groundnut+	Farmers practice	926 + 53	15150	7805	2.06
	pigeonpea (6)	Improved practice	1114 + 57	18780	11022	2.63

Table 114. Effect of package of practices on productivity of crops at ORP centers

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)
Arjia	Maize	Traditional cropping system	388
		Improved bio-diverse farming system	1252
	Wheat (3)	Farmers practice	710
		Recommended practice	1700
		Local variety	1390
		Untreated seed	1370
		22.5 cm spacing	1500
		No fertilizer	890
		No weeding	1380

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)
	Barley (1)	Farmers practice (Untreated seed & no fertilizer)	587
		Recommended package	1000
		Untreated seed	603
		No fertilizer	867
		Weed control	762
	Raya (1)	Farmers practice	189
		Recommended package	411
		Local variety	349
		No fertilizer	277
		Weed control	300
		No spray	300
	Taramira (2)	Farmers practice	143
		Recommended package	254
		Local variety	207
		No fertilizer	207
	Maize (11)	Farmers practice	1010
		Improved practice	2242
	Groundnut (6)	Farmers practice	937
		Improved practice	1509
	Pearlmillet fodder (5)	Farmers practice	18180
		Improved practice	33980
	Wheat (9)	Farmers practice	617
		Improved practice	1161
	Barley (5)	Farmers practice	364
		Improved practice	643
	Chickpea (6)	Farmers practice	143
		Improved practice	333
	Raya (2)	Farmers practice	406
		Improved practice	645
	Taramira (2)	Farmers practice	111
		Improved practice	192
Hisar	Greengram (5)	Farmers practice	480
		Package practice	690
	Mothbean (5)	Farmers practice	460
		Package practice	690
	Cluster bean (5)	Farmers practice	460
		Package practice	640
	Sesame (5)	Farmers practice	230
		Package practice	310
	Chickpea (3)	Control	460
		Package of practice (Endosulfan)	640
		Package of practice (Rhizobium culture)	690
		Package of practice (fertilizer)	600
		Package of practice (interculture)	650
		Package of practice	760
Solapur	Chickpea (4)	Farmers practice	573
		Improved practice	838
	Safflower (1)	Farmers practice	647
		Improved practice	1115
	Sunflower (2)	Farmers practice	510
		Improved practice	779

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)
	Maize (2)	Farmers practice Improved practice	1592 2195
	Sorghum (4)	Farmers practice Improved practice	748 1524
Arjia	Sesame (3)	Farmers practice Improved practice	172 300
	Blackgram (3)	Farmers practice Improved practice	62 102
	Greengram (3)	Farmers practice Improved practice	65 95
	Clusterbean (3)	Farmers practice Improved practice	248 467
	Sorghum fodder (5)	Farmers practice Improved practice	1562 2540
	Maize + black gram (maize equivalent yield) (6)	Farmers practice Improved practice	889 1294
	Groundnut + sesame (groundnut equivalent yield) (3)	Farmers practice Improved practice	963 1258

4.7. Integrated Weed Management

At Ranchi significantly higher grain yield of 1848 kg/ha was attained when weeds were removed with grubber, while weeding by dryland weeder gave a yield of 1714 kg/ha, compared to farmers' practice (1421 kg/ha).

At Ballowal Saunkhri, one hoeing at 21 DAS was superior with a pod yield of 1537 kg/ha, while application of pendimethalin @ 2.5 l/ha gave the 2nd best yield of 1499 kg/ha.

In pearlmillet at Hisar, a maximum grain yield of 1120 kg/ha and 2nd best gross returns of Rs.4320/ha were attained by weeding with kasola at 20 and 30 DAS. Weeding with wheel hand hoe at 20 and 30 DAS gave the 3rd best yield of 1030 kg/ha and a maximum gross returns of Rs.5540/ha.

In soybean at Indore, the weed-free treatment gave a maximum grain yield of 1062 kg/ha with a net returns of Rs.5055/ha and BC ratio of 1.68. Application of weedicide 'targa super' together with inter culture gave 2nd best yield of 1004 kg/ha with a net returns of Rs.4872/ha and maximum BC ratio of 1.71 **(Table 115).**

Table 115. Effect of weed management practices on productivity, gross and net returns of soybean at ORP, Indore

Treatments	Yield (kg/ha)	Gross net returns (kg/ha)	Net returns (kg/ha)	BCR
Farmers' practice	756	8316	3175	1.56
Weedicide (Targa super)	954	10494	4454	1.67
Weedicide + interculture	1004	11046	4872	1.71
Weed free	1062	11814	5055	1.68

4.8. Alternate Land Use and Farming Systems

In dhek based agro-forestry model at Ballowal Saunkhri, a maximum gross returns of Rs.13040/ha was attained with groundnut (pod yield of 652 kg/ha), followed by Rs.7125/ha with pearl millet (fodder yield of 28500 kg/ha) and Rs.3000/ha with blackgram grain yield of (150 kg/ha). The *rabi* crops of wheat, lentil and taramira failed due to severe moisture stress. In an assessment of groundnut – lentil, blackgram + wheat and pearl millet fodder – lentil under agri – horti model with guava and peach trees, a maximum gross returns of Rs.25040/ha was attained under groundnut – lentil system. This was followed by pearl millet fodder – lentil with Rs.6500/ha and blackgram – wheat with Rs.3080/ha. In *kharif*, groundnut gave a yield of 1252 kg/ha, blackgram gave 154 kg/ha and pearl millet fodder gave 26000 kg/ha. The *rabi* crops of lentil and wheat failed due to severe moisture stress in the season.

At Hisar, a higher grain yield of cluster bean of 570 kg/ha was attained under ber, while 520 kg/ha was attained under aonla. Greengram gave a yield of 520 kg/ha under ber and 440 kg/ha under aonla system. A mean cluster bean yield of 550 kg/ha was attained in the trial compared to 480 kg/ha of green gram under different horticultural species.

In an evaluation of groundnut, sorghum, pigeonpea and castor in a watershed area at Anantapur, groundnut gave a maximum yield of 830 kg/ha and net returns of Rs.5105/ha and 3rd best BC ratio of 1.70. Sorghum gave the 2nd best groundnut equivalent yield of 384 kg/ha with a net returns of Rs.3360/ha and maximum BC ratio of 2.40. Pigeonpea gave the lowest yield of 250 kg/ha with a net returns of Rs.1950/ha and 2nd best BC ratio of 2.08. Castor was the 3rd best with a groundnut equivalent yield of 320 kg/ha, lowest net returns of Rs.1800/ha and a BC ratio of 1.60 in the trial.

In a crop planning trial on marginal lands at Solapur, horsegram gave a higher mean yield of 393 kg/ha under custard apple compared to 310 kg/ha under ber system.

In a bio-diverse farming system model with maize, sorghum, blackgram, horsegram, groundnut, sesame, ber, jatropha and medicinal crops at Arjia, the improved system gave a maize equivalent yield 1252 kg/ha compared to the traditional cropping system (388 kg/ha) **(Table 116 & 117).**

Table 116. Effect of trees and crops on productivity, gross and net returns at different ORP centers

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	BCR
Anantapur	Groundnut (1)	Groundnut	830	12450	5105	1.70
	Alternate crops to groundnut	Sorghum	384	5760	3360	2.40
		Pigeonpea	250	3750	1950	2.08
		Castor	320	4800	1800	1.60

Agro-horticulture at Hisar (ORP)

Silvipasture system with Stylostanthus hamata at Sola ka kheda, ORP village, Arjia.

Table 117. Effect of trees on productivity of crops at different ORP centers

Centre	Crop (No. of farmers)	Treatments	Yield (kg/ha)	Gross returns (Rs/ha)
B.Saunkhri	Dhek (3 year old)	Dhek + groundnut	652 (K)	13040
		Dhek + blackgram	150 (K)	3000
		Dhek + pearl millet fodder	28500(K)	7125
	Guava (3 year old)	Guava + groundnut	1252	25040
		Guava + blackgram	154	3080
		Guava + fodder	26000	6500
Hisar	Agri-horti system	Ber + green gram	520	
		Aonla + green gram	570	
		Aonla + cluster bean	520	
	Horti-pastoral system	Existing grazing system		
		Improved horti-pastural system		
Solapur	Agri-horticultural system (4)	Custard apple & horse gram	393	
		Ber & horse gram	310	
Arjia	Bio-diverse farming model (maize equivalent yield)	Traditional cropping system	388	
		Improved Bio-diverse farming system	1252	

K : Kharif

5. Front Line Demonstrations

1. Pulses

During 2005-06, 78 Front Line Demonstrations (FLD) were conducted on greengram (20) at Phulbani; chickpea (5) at Agra; Pigeonpea (5) and chickpea (6) at Solapur; blackgram (7) and greengram (16) at Kovilpatti; pigeonpea (6) and chickpea (6) at Faizabad; chickpea (4) and lentil (3) at Ballowal saunkhri. The results on percentage yield increase, cost of cultivation, gross returns and BC ratio under FLD and farmers practice at different centers are given below:

The improved practice gave a yield increase of 44.8% in greengram at Phulbani with a gross returns of Rs.93,200/ha with a BC ratio of 1.39. At Agra, a 25.5% yield increase of chickpea was attained with improved practice. A yield increase of 29.9% in pigeonpea and 23.2% in chickpea were attained at Solapur. The improved practice gave a mean yield of 1219 kg/ha with a gross returns of Rs.19498/ha and BC ratio of 1.87 incase of pigeonpea and 1071 kg/ha of yield, Rs.18745/ha of gross returns and BC ratio of 1.95 incase of chickpea under FLDs. At Kovilpatti, a mean yield of 795 kg/ha of blackgram and 831 kg/ha of greengram were attained compared to farmers practice with 625 and 641 kg/ha. Thus there was a yield increase of 21.4 and 22.9% in blackgram and greengram crops respectively. The improved practice gave a gross returns of Rs.15900/ha with a BC ratio of 1.76 in case of greengram under the FLDs. The farmers practice gave Rs.12500/ha and BC ratio of 1.63 incase of blackgram and Rs.12940/ha and 1.65 in greengram in the trials. At Faizabad, a mean pigeonpea yield of 2216 kg/ha with a yield increase of 33.4% was attained compared to farmers practice with a yield of 1475 kg/ha. Incase of chickpea at Faizabad, a yield increase of 35% was attained with improve practice. The farmers practice gave a chickpea yield of 1312 kg/ha, while the improved practice gave 2023 kg/ha in the trials.

At Ballowal Saunkhri, the improved practice gave a higher lentil yield by 52.6% compared to farmers practice. The improved practice in chickpea gave a mean yield of 1730 kg/ha compared to farmers practice with 1010 kg/ha at Rewa. The improved technology gave a yield increase of 20.7% over farmers practice. A higher BC ratio of 3.29 was attained under improved practice compared to 2.59 under farmers practice in the FLDs conducted during rabi season. In one FLD conducted on blackgram with DU – 4 variety at Rewa, a grain yield of 800 kg/ha was attained in an area of 0.4 ha.

At Varanasi, a mean yield of 1540 kg/ha was attained in pigeonpea with improved practice compared to 850 kg/ha under farmers practice. . The improved practice gave a gross income of Rs.32200/ha compared to farmers practice with Rs.17575/ha. In greengram, the improved practice gave a higher yield of 850 kg/ha with a yield increase of 38.8% compared to 520 kg/ha attained with farmers practice. The improved practice provided a gross returns of Rs.23680/ha, while the farmers practice gave Rs.14890/ha. Higher chickpea yield of 1275 kg/ha with a yield increase of 41.2% were attained with improved practice compared to the farmers practice (750 kg/ha.) The improved practice gave a gross income of Rs.27788/ha against Rs.16485/ha attained with farmers practice **(Table 118).**

Table. 118. Superiority of improved practice over farmer's practice for pulses at AICRPDA centers

Center	Crop	Variety	No.	Area (ha)	Yield (kg/ha)		Inc (%)	Cost of cultivation (Rs/ha)		Gross returns (Rs/ha)		Net returns (Rs/ha)		BC	
					FLD	FP		FLD	FP	FLD	FP	FLD	FP	FLD	FP
Phulbani	Greengram	PDM-54	20	5.0	466	257	44.8	6698	4220	9320	5140	2622	920	1.39	1.22
Agra	Chickpea	RGS-44	5	2.0	917	683	25.5	7810	7033	22025	16735	14215	9702	1.79	1.38
Solapur	Pigeonpea	BSMRR-853	5	2.0	1219	854	29.9	10392	8236	19498	13667	9106	5431	1.87	1.65
	Chickpea	Vijay	6	2.4	1071	822	23.2	9590	8363	18745	14388	9156	6025	1.95	1.71
Kovilpatti	Blackgram	VBN-4	7	2.8	795	625	21.4	9014	7681	15900	12500	6886	4810	1.76	1.63
	Greengram	CO6, VBN2	16	6.4	831	641	22.9	9234	7864	16740	12940	7505	5076	1.81	1.65
Faizabad	Pigeonpea	NA-1	6	2.4	2216	1475	33.4								
	Chickpea	Awarodhi	6	2.4	2023	1312	35.1								
Bsaunkhri	Chickpea	PBG-1	4	1.2											
	Lentil	LL-669	3	0.5	213	101	52.6								
Rewa	Chickpea	JG – 322	5	2.0	1273	1010	20.7							3.29	2.59
	Blackgram	DU – 4	1	0.4	800										
Varanasi	Pigeonpea	NA-1, Bahar	3	1.2	1540	850	44.8			32200	17575				
	Greengram	Malviya Janchetana	2	0.8	850	520	38.8			23680	14890				
	Chickpea	Avarodhi	3	1.2	1275	750	41.2			27788	16485				

*.Increase in gross returns Inc : Increase in yield (%) BC : Benefit Cost Ratio FLD : Front line demonstration FP : Farmers practice

2. Oilseeds

During 2005-06, 104 FLDs were conducted on groundnut (43) at Phulbani; mustard (6) at Agra; Soybean (4), *Kharif* sunflower (6) *rabi* sunflower (4) and Safflower (7) at Solapur; mustard (6) at Faizabad; castor + cowpea (5), castor + greengram and castor - greengram (10) at Dantiwada; sunflower (5) at Bijapur; raya (3) at Ballowal Saunkhri. The results are discussed below:

The improved practice for groundnut gave a higher mean yield of 1290 kg/ha with a yield increase of 47.9% over farmers practice at Phulbani. At Agra, the improved practice gave a higher seed yield of 1618 kg/ha compared to farmers practice with 1381 kg/ha. The improved practice gave a yield increased of 14.6%, gross returns of Rs.27431/ha and BC ratio of 2.6 compared to this the farmers practice which gave a gross returns of Rs.23466/ha with BC ratios of 2.39.

In soybean, at Solapur a yield of 1308 kg/ha was attained with improved practice compared to 815 kg/ha with farmers practice. In sunflower in *kharif* and *rabi* seasons, the improved practice gave a yield of 1084 kg/ha in *kharif* and 905 kg/ha in *rabi* with a yield increase of 27.0 and 30.4% respectively compared to the farmers practice. In safflower, a yield of 1221 kg/ha was attained with improved practice compared to 774 kg/ha with farmers practice. There was a yield increase of 36.6% with improved practice compared to farmers practice. At Faizabad, a mean yield of 1346 kg/ha with a yield increase of 36.8% was attained in mustard with improved practice over farmers practice. (850 kg/ha).

In castor + cowpea at Dantiwada, the improved practice gave a yield of 585 kg/ha of castor and 321 kg/ha of cowpea compared to the farmers practice with a sole castor yield of 692 kg/ha. The improved practice gave a maximum gross returns of Rs.12211/ha with an increase of 19.9% over farmers practice (Rs.9822/ha). In castor + greengram inter cropping trials a yield of 580 kg/ha of castor and 178 kg/ha of greengram were attained compared to 643 kg/ha under farmers practice. The improved practice gave a maximum gross returns of Rs.12578/ha compared to farmers practice with Rs.9022/ha. At Bijapur, a higher seed yield of 776 kg/ha with a increase of 12.2% was attained compared to farmers practice with 681 kg/ha. In case of raya at Ballowal Saunkhri, a yield increase of 52.9% was attained with improved practice compared to farmers practice. (178kg/ha). At Rewa, a higher yield of 556 kg/ha with a yield increase of 19.8% was attained in Linseed compared to farmers practice (446 kg/ha). At Varanasi, the improved practice gave a mean yield of 1300 kg/ha compared to 900 kg/ha attained with farmers practice. There was a yield increase of 30.8% under improved practice over farmers practice. The improved practice gave a gross returns of Rs.25500/ha compared to farmers practice with Rs.16970/ha in the trials. **(Table 119)**

Table 119. Superiority of improved practice over farmers practice for oilseeds at AICRPDA centers

Center	Crop	Variety	No.	Area (ha)	Yield (kg/ha)		Inc (%)	Cost of cultivation (Rs/ha)		Gross returns (Rs/ha)		Net returns (Rs/ha)		BC	
					FLD	FP		FLD	FP	FLD	FP	FLD	FP	FLD	FP
Phulbani	Groundnut	Smruthi	43	6.0	1290	672	47.9	13153	9475	22122	12096	8969	2621	1.68	1.28
Agra	Mustard	Rohini, Pbold	6	2.4	1618	1381	14.6	7503	6967	27431	23466	19928	16499	2.67	2.39
Solapur	Soybean	JS-335	4	1.6	1308	815	37.7	8832	7565	15372	9579	6540	2014	1.74	1.26
	Sunflower (K)	MSFH-17	6	2.4	1084	791	27.0	8116	6816	14639	10681	6523	3865	1.81	1.58
	Sunflower (R)	KBSH-1	4	1.6	905	630	30.4	8413	7028	14397	10391	6524	3363	1.80	1.49
	Safflower	Bhima	7	2.8	1221	774	36.6	7751	6215	15871	10058	8120	3844	2.07	1.65
Faizabad	Mustard	Varuna	6	2.4	1346	850	36.8								
SK Nagar	Castor + cowpea		5	2.0	585 (321)	692	19.9*			12211	9822				
	Castor + greengram		5	2.0	580 (178)	643	23.9*			12578	9022				
	Castor - greengram		10	4.0	300 (126)	393	13.3*			11523	9813				
Bijapur	Sunflower		5	2.0	776	681	12.2								
Bsaunkhri	Raya	RRLM-619	3	0.45	378	178	52.9								
Rewa	Linseed	JL – 23	6	2.0	556	446	19.8							2.08	1.50
	Soybean	JS - 335	5	2.0	2.40										
Varanasi	Linseed	Garima	2	0.8	1300	900	30.8			25500	16970				

*.Increase in gross returns Inc : Increase in yield (%) BC : Benefit Cost Ratio FLD : Front line demonstration FP : Farmers practice

On–farm Trials

Four non-ORP centers viz., Kovilpatti, Bijapur, Dantiwada and Agra have conducted on-farm trials (OFT) during 2005-06. The OFTs were on cotton (12 trials) and sorghum (12) at Kovilpatti; sunflower (12) at Bijapur; pearlmillet (7), castor (7), cotton (7), chickpea (7) and mustard (7) at Dantiwada; and mustard (10) at Agra.

Twelve OFTs were conducted on cotton in an area of 4.8 ha at Kovilpatti. The improved practice gave a mean yield of 671 kg/ha with an increase of 23.4% over farmers practice (514 kg/ha) the improved practice gave a higher gross returns of Rs.14771/ha, net returns of Rs.5496/ha and BC ratio of 1.59 as against Rs.11310/ha, Rs.8264/ha and 1.37 under farmers practice. Twelve OFTs on sorghum were conducted in an area of 4.8 ha at Kovilpatti. A mean yield of 2966 kg/ha was attained with improved practice with an increase of 18.6% over farmers practice with a yield of 2413 kg/ha. The improved practice gave a higher gross returns of Rs.14829/ha, net returns of Rs.7549/ha and BC ratio of 2.04 as against Rs.12064/ha, Rs.5541/ha and 1.86 under farmers practice.

Twelve OFTs on sunflower were conducted in an area of 4.8 ha at Bijapur. A mean yield of 653 kg/ha was attained with improved practice with a yield increase of 19.4% over farmers practice with a yield of 526 kg/ha.

Seven OFTs were conducted on pearl millet at Dantiwada with sowing across the slope, compartmental bunds, ridges and furrows and normal sowing treatments. Among the four treatments tested, compartmental bunds gave a maximum yield of 1326 kg/ha with a yield increase of 48.7% compared to normal sowing with a minimum yield of 892 kg/ha. Ridges and furrows was the 2nd best treatment with a yield of 1264 kg/ha and yield increase of 41.7% over normal sowing. Sowing across the slope gave a mean yield of 1168 kg/ha with a yield increase of 30.9% in the trials. Three hybrids and local variety of castor were tested under 7 on-farm trials in an area of 2.8 ha. The hybrid GCH-5 was superior with a maximum yield of 1380 kg/ha and yield increase of 66.7% over local variety. This was followed by GCH-6 with 1288 kg/ha and a yield increase of 55.6% and GCH-4 with 1170 kg/ha having a yield increase of 42.4% over local variety. The local variety gave a minimum mean yield of 828 kg/ha in the trials. Based on 7 on-farm trials of cotton with four varieties tested at Dantiwada, G-CO-21 was superior with a yield of 1051 kg/ha having a yield increase of 45.5% over local variety with a yield of 722 kg/ha. V-797 was the 2nd best with a yield of 936 kg/ha having a yield increase of 29.7%, while G-CO-13 was the 3rd best with a yield of 892 kg/ha having a yield increase of 23.5%. The improved practice of rhizobium seed treatment for chickpea varieties GG-1 and GG-2 was superior compared to no seed treatment under 7 OFTs at Dantiwada. The improved practice gave a higher yield of 1293 kg/ha with a yield of 12.8% under rhizobium seed treatment for GG-2 variety compared to 1057 kg/ha without rhiobium treatment. In case of GG-1 variety, the rhizobium seed treatment gave 1081 kg/ha having a yield increase of 14.2% compared to without rhizobium seed treatment (946 kg/ha). Bio-902 variety of mustard was found to be superior at Dantiwada based on 7 OFTs conducted in farmers fields. This gave a maximum seed yield of 1248 kg/ha with a yield increase of 52.9% over local variety (816 kg/ha). GM-3 was the 2nd best with a yield of 1221 kg/ha and a yield increase of 49.6%, while GM-2 was the 3rd best with a yield of 1009 kg/ha having a yield increase of 23.6% in the trials.

Among 4 varieties of mustard viz., Rohini, Pusa bold, Bio-902 and local (T-59) tested under 4 OFTs at Agra, a maximum of 1820 kg/ha with a yield increase of 16.9% was attained with Bio-902 variety. Pusa bold was the 2nd best with a yield of 1685 kg/ha and had a yield increase of 8.3% over local variety. Rohini was the 3rd best with a yield of 1648 kg/ha and a yield increase of 5.9%. The local variety provided a minimum yield of 1556 kg/ha in the trials. Two OFTs each were conducted on row spacing, fertilizer N and P doses and application of Sulphur for mustard at Agra. In the trials on row spacing, the improved practice of 45 cm spacing was superior with a seed yield of 1498 kg/ha with 9.5% yield increase over the farmers practice of 30 cm spacing (1368 kg/ha). The improved row spacing gave a higher net returns of Rs.18798/ha with BC ratio of 2.83 compared to farmers practice with Rs.16588/ha with BC ratio of 2.49. In the trials on N and P fertilizer application, the improved practice of 60 kg N + 40 kg P/ha was superior with a yield of 1755 kg/ha having a yield increase of 26.8% over the farmers practice. The farmers practice of 32 kg N + 23 kg P/ha gave a yield of 1384 kg/ha. The improved fertilizer application gave a higher net returns of Rs.21335/ha having a BC ratio of 2.51, while the farmers practice gave Rs.15940/ha with BC ratio of 2.10. In the trials on Sulphur application, a maximum yield of 1600 kg/ha with a yield increase of 14.9% was attained compared to farmers practice of no Sulphur application (1368 kg/ha). The improved practice of Sulphur application gave a higher net returns of Rs.19650/ha having a BC ratio of 2.68, while the farmers practice gave Rs.16970/ha with BC ratio of 2.58.**(Table 120).**

Table 120. On–farm trials on different crops at AICRPDA centers during 2005-06

Center	Crop/ Treatment	Area (ha)	Yield (kg/ha)	Inc	GR	CC	NR	BC
Kovilpatti/Cotton (12)	Improved practice	4.8	671	23.4	14771	9275	5496	1.59
	Farmers practice		514		11310	8264	3046	1.37
Kovilpatti/Sorghum (12)	Improved practice	4.8	2966	18.6	14829	7280	7549	2.04
	Farmers practice		2413		12064	6523	5541	1.86
Bijapur/Sunflower (12)	Improved practice	4.8	653	19.4				
	Farmers practice		526					
Dantiwada/Pearlmillet (7)	Sowing across the slope	0.7	1168	30.9				
	Compartment bund	0.7	1326	48.7				
	Ridge & furrow	0.7	1264	41.7				
	Normal sowing	0.7	892					
Dantiwada/Castor (7)	GCH-4	0.7	1179	42.4				
	GCH-5	0.7	1380	66.7				
	GCH-6	0.7	1288	55.6				
	Local	0.7	828					
Dantiwada/Cotton (7)	V-797	0.7	936	29.7				
	G-Co 13	0.7	892	23.5				
	G-Co21	0.7	1051	45.5				
	Local	0.7	722					
Dantiwada/Chickpea (7)	Rhizobium + GG-1 (IP)	0.7	1081	14.2				
	GG-1 (FP)	0.7	946					
	Rhizobium + GG-2 (IP)	0.7	1293	12.8				
	GG-2	0.7	1057					
Dantiwada/Mustard (7)	GM-2	0.7	1009	23.6				
	GM-3	0.7	1221	49.6				
	Bio-902	0.7	1248	52.9				
	Local	0.7	816					
Agra/Mustard (4)	Rohini		1648	5.9				
	Pusa bold		1685	8.3				
	Bio-902		1820	16.9				
	Local (T-59)		1556					
Agra/Mustard (6)	Row spacing 45 cm (IP)		1498	9.5		6660	18798	2.83
	Row spacing 30 cm (FP)		1368			6660	16588	2.49
	60 kg N + 40 kg P/ha (IP)		1755	26.8		8500	21335	2.51
	32 kg N + 23 kg P (FP)		1384			7580	15940	2.10
	Sulphur @ 30 kg/ha (IP)		1600	14.9		7350	19650	2.68
	No sulphur (FP)		1368			6660	16970	2.58

Values in parentheses indicate number of trials GR: Gross returns (Rs/ha) Inc : Increase (%)
CC: Cost of cultivation (Rs/ha) NR: Net returns (Rs/ha) BC: Benefit-cost ratio

6. AP Cess Fund Ad-hoc Projects

During the period there were 17 projects. Out of these 5 were concluded. Highlights of the work done are presented below :

RF 303 083 4017: Crop-crop diversity as key component of IPM for dryland crop pests (M. Srinivasa Rao, Central Research Institute for Dryland Agriculture, Hyderabad)

Creation of crop diversity by the introduction of one crop in to another crop is known as crop-crop diversity. Intercropping and mixed cropping systems are more popular forms of crop-crop diversity practiced in rainfed agriculture. These systems provide opportunities to create situations that are less prone to pests compared to the single crop situations or the monocultures. Research was conducted at on-station and in farmers' fields on crop-crop diversity as key component of Integrated Pest Management in pigeonpea. The results of the research indicated that medium duration pigeonpea, in addition to being attacked by fewer pests, exhibited less flower shedding during dry spells, making it more suitable to dryland conditions. Pigeonpea intercropped with sorghum, greengram or groundnut is better protected from adverse climate as well as pest attacks, resulting in higher yields and economic returns. The adoption of low external input integrated pest management module consisting of sequential application of neem seed kernel extract 5%, neem oil 5%, extract of V. negundo 1/10 w/w, pongamia oil 5%, erection of bird perches and mechanical collection of larvae were found effective in managing/controlling the pests. Choice of medium duration pigeonpea and intercropping with sorghum, greengram or groundnut may be integrated into the effective LEIIPM module as a component.

RF 303 083 4018: Interaction of elevated carbondioxide and water deficit on seed viability, germination and initial plant establishment of dryland crops (M. Vanaja, Central Research Institute for Dryland Agriculture, Hyderabad)

The studies indicated that elevated CO_2 showed positive response in rainfed crops. The pulse crops in general responded better in enhanced CO_2 when compared with cereals and oilseeds. Elevated CO_2 significantly increased even with moisture stress conditions on germination percentage, speed of germination, emergency index and vigour index of black gram. The root and shoot length of black gram decreased under moisture stress at both CO_2 levels (ie., 365 ppm and 600 ppm) compared to irrigated conditions. The response of leaf, stem, root and total plant weight was positive with elevated CO_2. The root: shoot ratio at elevated CO_2 was negative (-3.2%) under irrigated was positive (4.8%) under moisture stress conditions. Increase of root: shoot ratio under moisture stress conditions indicates that allocation of assimilates was greater to roots under stress. High CO_2 caused significant increase in growth both in terms of yield and dry matter production. In blackgram improvement in pod number, pod weight, seed size was noticed under CO_2 enrichment.

RF 303 083 4019: Crop diversification for sustainability of drylands through dye crops (G. Pratibha, Central Research Institute for Dryland Agriculture, Hyderabad)

The project was initiated in 2003. Three dye yielding crops viz., henna, Indigo and Bixa were tested.

Bixa: Different organic and inorganic source of fertilizers influenced the yield and bixin content significantly. Vermicompost recorded higher bixin content over other fertilizers. Red colour genotype (776 kg/ha) recorded higher yields over green colour (671 kg/ha). Whereas bixin content was not influenced by the genotypes.The bixa shell was composted by various methods. The decomposition was faster in vermicomposting when compared to other methods. The same was demonstrated in an on-farm study and the farmer has produced around 10 t of vermicompost within 3 months by using his shell and other farm waste. He used the same vermicompost for his other crops.

Indigo: Highest biomass yields were recorded in FYM (12783 kg/ha) and vermicompost (12301 kg/ha) over castor cake and inorganic fertilizers. 60 kg/ha of P_2O_5 recorded higher dye yield and Indigo tin content over 0, 30, 60, 90 kg/ha. Modifications in extraction process were made for higher dye recovery. Microbial cultures added during fermentation improved the dye yield and Indigotin content significantly. The oxidation method was modified. A shaker with aerator was designed and fabricated. The new shaker helped in better oxidation efficiency, aeration, enhanced the dye recovery and quality, less laborious and time consuming, better on farm adaptability.

Henna: The results indicated that, FYM recorded 14% and 10% higher yields and lawsone content over no FYM. 60 kg N/ha and 30 kg P_2O_5/ha recorded higher yield and lawsone content over 0, 30, 90 kg N and 0 and 90 kg of phosphorous. Irrigation during off-season recorded significantly higher yield over rainfed crop and vermicompost recorded higher yield and lawsone content over other sources of fertilizers tried.

The indigo crop residues after dye extraction also had higher nutrient content hence the wastes were vermicomposted. The vermicompost had higher NPK contents. Hence this compost can be applied to the field. Various crude extracts of henna, Indigo and Andrographis were evaluated against 2nd instar larvae of *S.litura* under choice conditions by following leaf dip method. Data on leaf area consumed, larval length and weight were recorded. Among these crude extracts of indigo fermented liquor after dye extraction exhibited antifeedant properties.

RF 303 083 4020: Studies on augmentation of green biomass for integrated nutrient management in dryland crop production (M. A. Sankar, University of Agricultural Sciences, Bangalore)

Studies on relative performance of Green Manure on Production potential of dryland crops showed that incorporation of Glyricidia gave significantly higher pod yield (1227 kg/ha), haulm yield (1745 kg/ha), shelling percentage (47.8), seed germination (97%) and vigour index (160.05). The increase in pod yield is 28% and 26% by incorporation of glyricidia as compared to Daincha and Sunhemp respectively. Higher OC (0.5%), Mn (20.02 ppm), Cu (1ppm), available N (220 kg/ha), P (75 kg/ha), K (145kg/ha), Zn (1.25 ppm), Fe (35.2 ppm) were observed significantly with glyricidia incorporation. Similary, higher plant uptake of N (72.2 kg/ha), P (13 kg/ha), Zn (140 g/ha), Fe (24.50 g/ha), Cu (35 g/ha). were also observed. In Finger millet, incorporation of Eupatorium gave significantly higher average grain yield (3800 kg/ha), straw yield (4930 kg/ha), and BC ratio (3.16). The yield increase was 32% and 26% with incorporation of Eupatorium compared to sunhemp and daincha respectively. Significantly higher available N, P_2O_5, K_2O are observed with incorporation of sunhemp, while higher N, P, K, Zn, Fe, Mn, Cu are observed with Eupatorium incorporation which also influenced seed quality in respect of higher seed germination and vigour index. Incorporation of Eupatorium encouraged the activity of soil microbes i.e., actinomycetes, phosphate solubilizers, rhizobium and free living nitrogen fixers, along with maximum soil activity in initial stages.

Integrated Nutrient Management with Green Leaf Manure in Groundnut - fingermillet based sequence cropping system: Application of glyricidia (to supply 100%N + recommended P and K + PSB (*Bacillus sps*)) as a green manure significantly increased pod yield in groundnut (1497 kg/ha), haulm yield (1863 kg/ha), shelling percentage (58%), higher seed germination percentage (98) and seed vigour index (194). Incorporation of glyricidia (to supply 100%N + recommended P and K) gave significantly higher grain yield (3940 kg/ha), and straw yield (5240 kg/ha). Integrated nutrient management with green leaf manure improved micronutrient status (Zn, Fe, Cu) and nutrient uptake in groundnut (N, P, K, Zn, Fe, Mn and Cu) along with improvement in seed germination and vigour index. Application of enriched compost prepared by normal composting + rock phosphate and PSB + azotobacter gave higher grain yield (2754 kg/ha), seed yield (3321 kg/ha) with grain yield increase of 32.5% and 45% with application of enriched compost compared to compost with 25% farm waste + 75% glyricidia green leaf manure +PSB and azotobacter enfixer. Enriched compost also highly influenced available N, Zn, Fe, Mn and Cu in the soil and higher uptake of N, P, K, Fe, Mn and Cu in finger millet.

Methods of pruning to increase biomass production in glyricidia: Significantly higher biomass yield of 113.9 t/ha and 97.14 t/ha was obtained by pruning to base of glyricidia at 90 and 150 days. However, pruning at 150 days at base significantly resulted in higher average biomass yield of 99.5 t/ha compared to 0.5 and 1m height. Planting glyricidia at 90 cm x 90cm gave significantly higher biomass yield of 151-163 t/ha. Glyricidia seed treatment in hot water gives better germination and establishment. Fresh seeds of nine and twelve month old cuttings put forth better germination and establishment.

RF 303 083 4021: Evaluation of Regenerative Agricultural Technology with low external inputs (V.Maruthi, Central Research Institute for Dryland Agriculture, Hyderabad)

In order to restore and revitalize the soil from degradation, it is necessary to extract solutions from the indigenous knowledge system and integrate with the existing technologies. In this context, cattle shed bedding with groundnut shell was done to prepare groundnut shell manure (GSM-1 tonne groundnut shell manure ha^{-1} + Farmers' practice) and experimented using it in the farmers' fields in comparison with the Farmers' Practice (FP-1 t FYM ha^{-1} + 17.5 N +36.3 P_2O_5 + 17.5 K_2O every year), groundnut shell as such (1 t groundnut shell ha^{-1} + Farmers' practice), compost (1t compost ha^{-1} + Farmers' practice) and regenerative treatment (complete organics-1t GSM +1 t compost +1t FYM ha^{-1}). The cropping systems at farmers' fields were *Kharif* groundnut crop (KG), Castor-groundnut system (C-G) and Groundnut–groundnut system (G-G). The salient findings are: with no dryspells during 2005-06, the groundnut yields were higher by nearly 3-4 times over the yields of 2004-2005 which experienced two dryspells at flowering and pod filling stages. In specific, yields of groundnut shell manure (GSM) applied fields were higher by 10-11% in the only *kharif* groundnut crop over farmers' practice, increased yields ranged from 6% and 25% in case of Castor-groundnut (C-G system) system during *kharif* and *rabi* respectively, while it was 24% in both *kharif* and *rabi* in Groundnut-groundnut system (G-G system). However, the lowest yield after Farmers' practice (FP) was recorded by the regenerative treatment (Complete organics) in all the systems. Improvement in its effect was observed more with the G-G system, followed by C-G system and *kharif* groundnut due to better soil physical and chemical conditions besides both (all) crops being legumes. Due to the combined effect of both soil moisture and the availability of nutrients during 2005-06, the percent filled pods in groundnut was increased by 20-34% while 12-21% increased capsules per plant was observed in castor. Since the crop experienced no drought, all the treatments including FP expressed nitrogen sufficiently. Presence of high nitrogen in the haulms at harvest, which was observed in the GSM applied plots, is an added advantage for the fodder. Therefore, preparation of groundnut shell manure by utilizing the groundnut shell and its application can improve soil resilience over time to face intermittent droughts, which are unpredictable.

RF 303 083 4022: Assessment of adoption and impact of IPM in rainfed crops (C.A.Rama Rao, Central Research Institute for Dryland Agriculture, Hyderabad)

The project was initiated in May 2004 with the major objective of examining the adoption and impact of IPM practices in three crops, viz., cotton, groundnut and pigeonpea in Guntur, Anantapur and Rangareddy districts, respectively. The project involves collection of primary data related to farm and household particulars of IPM-adopters and non-adopters, which will be analyzed to identify the factors that influence adoption of IPM and the subsequent impact at farm level. Farmers growing the three target crops were found to follow a wide range of practices to manage the pests. The adoption of different components of IPM was found to be varying. On the whole, the cultural components of IPM such as summer ploughing (more than 90% of IPM farmers), intercropping were adopted by more farmers. The adoption of biological components such as NPV, *Bt* was observed to be limited because of the constraints in availability as well as the lack of proper understanding on the application methods and efficacy of these components. All the IPM farmers were found to use pheremone traps in case of cotton. Apart from age and education of the farmers, the ability to recognize the insect pests and participation in CBOs were found to influence IPM adoption positively. An adoption score was computed as a weighted average of adoption of different components. Based on this score, adopters were classified into low, medium and high adoption categories. Adoption of IPM was observed to be more in case of cotton where the incidence of insect pests is high compared to other two crops. The adoption score was found to have a significantly negative relationship with use of chemical insecticides and total plant protection expenditure. The adoption of IPM was found to lead to reduction in use of insecticides, reduced cost of cultivation and increased net returns. Another important benefit associated with adoption of IPM was the reduction in incidence of sick events arising from exposure to insecticides. Use of new generation insecticides was found to discourage IPM adoption as farmers find them more effective.

RF 303 083 4023: Assessment of impact of sustainable land management practices initiated in developed/treated watersheds in rainfed agro-ecoregion of Telangana A.P – a GIS based study (Kausalya Ramachandran, Central Research Institute for Dryland Agriculture, Hyderabad)

During the year three watersheds were selected in Agroecological subregion 7.2 in Andhra Pradesh with an objective to generate baseline information to facilitate temporal study of sustainability status in watersheds. Micro – watersheds were delineated and locations of Soil and Water Conservation Structures were georeferenced using a hand-held GPS. To assess soil erosion status, slope maps were generated and satellite imagery of 1998, 2001, 2004 and 2005 were analysed and droped over slope maps to identify soil erosion hazard in Gollapalli, Dontanpalli and Pamana villages. In case of Dontanpalli, a detailed study of soil erosion status was carried out using satellite imagery of pre- and post- watershed project period. To assess agricultural sustainability in treated micro-watersheds, soil fertility status was studied. Over 210 soil samples were collected from six micro -watershed located in the three villages, and analysed for 12 physico-chemical and biological parameters. A soil fertility database and maps were created using ArcGIS. The results were used to assess sustainability of treated watersheds. In order to facilitate the farmers to use correct dose of fertilizers, soil status report were given to each of them. Over 200 farm families were interviewed based on structured questionnaire for gathering information on their socio-economic status, agricultural production and productivity of crops to assess impact of Watershed Development Program on their household, field and on the village economy. Database have been created in MS-Access for the various modules of this project – soil fertility status, household information, socio-economic status of farmers, farm holding characterization, credit facility, cropping pattern, crop choice, marketing facility, etc.

RF 303 083 4024: Organic carbon assessment and its maintenance under rainfed production system (Ch. Srinivas Rao, Central Research Institute for Dryland Agriculture, Hyderabad)

The influence of continuous cropping, fertilization, groundnut shells and FYM addition on Alfisol at Anantapur center indicated that mean yields of groundnut were higher with use of nutrients either with inorganic or organic over control after 20 years of experimentation. During initial 2 to 3 years, a moving average of pod yield in groundnut with 100% organics (5t of FYM/ha) was inferior compared to the control. But in subsequent years a gap between control and other fertilizer and manorial practices gradually widened. There was an overall decline in trends in pod yield of groundnut during the 20 year period. Use of 50% of NPK with 4 t of groundnut shells per hectare recorded highest Sustainability Yield Index (SYI) with 0.492 followed by 100% NPK (0.471), 50% NPK + 4 t FYM/ha (0.460), 5 t FYM/ha (0.410) and control (0.400). Soil pH under 100% NPK and control were acidic in surface layers were 50% NPK + groundnut shells or 50% NPK + FYM and 100% organic showed neutral pH. 100% NPK combination showed highest electrical conductivity ranging from 0.07 to 0.123 $dsm^{-1.}$ Surface layer (0-20 cm) showed lower EC levels compared to deeper layers (20-40 cm). Use of 100% NPK lowered lime content (0.18%) and lime content increased with depth upto 80 cm in INM treatments. Soils under all the treatments showed an increased CEC upto 60 cm followed by decrease thereafter. In surface layer (0-20 cm) water retention at $1/3^{rd}$ bar increased from 9.5% in control to 16.75% in INM practices. Available N varied from 37.5 kg/ha to 78.5 kg/ha in control, from 60-143 kg/ha in 100%

NPK and from 60.1-144.5 kg/ha in 50% NPK + 4t groundnut shells/ha. Considerable build of available P was recorded in all fertilizer and manorial treatments. Depletion of available K was observed in absence of K fertilizer (control) compared to other fertilizer and manorial treatments. All organic treatments such as 50% NPK + 4t of groundnut shells showed higher exchangeable Ca compared to control and 100% NPK. Exchangeble Mg status in surface soils varied from 1.21 me 100 g^{-1} (control) to 3.2 me 100 g^{-1}(100 %organic). Control profile showed available S from 4.1-5.2 kg/ha, while 50 % NPK+ 4t FYM/ha profile recorded 11-29.6 kg/ha indicating significant build in available S status in organic treatments. Irrespective of nutrient management practices, all soils are found to be Zn deficient. Organic materials showed a slightly higher available Fe compared to control and 100 % organic. Slight improvement in available Mn status of soil was observed over control and 100% NPK. Soil profile under NPK treatment showed a relatively lower Cu content and all the soil layers were sufficient in Cu status. Boron content of all the treatments was found to be deficient. However, addition of organic manures over 20 years improved the B status only marginally. Continuous addition of organic C amendment for 20 years improved organic C content significantly with a range of 0 .15-0.31. Highest total N was found in organic treatments followed by INM practices. Considerable improvement in microbial biomass Carbon (BMC) and Dehydrogenase Activity (DHA) was observed with organic amendments. While 50% NPK +4t FYM and 100% organics maintained highest Aryl Sulphatase Activity (ASA) and also Urease activity. Population of fungi, bacteria and actinomycetes were higher in organic and organic + inorganic combinations. Thus results from 20 years long term studies in INM indicated that addition of organic manures improved soil organic C, MBC, enzyme activity and microbial population followed by organics + inorganics. Renewable organic sources such as groundnut shells could be a possible option along with FYM to improve soil organic and biological activity of soils under arid environment.

RF 303 083 4025: Integrated Farming System models for sustainable productivity and income of small and marginal rainfed rice farms of Chattisgarh (A.L. Rathore, Indira Gandhi Agricultural University, Raipur)

Six farming system models were evaluated at the university farm for 0.40, 0.80 and 1.0 ha land holdings with farm pond alone and farm pond with shallow dug well from 2005-06 to 2006-07. The major objective was to develop an appropriate integration of crops, livestock and fish for round the year employment, income and sufficient food to farm family on the farm. Of the total land in the six models, cultivation of crops was done in 88% area of the farm in which rice, oilseed (soybean), pulse (pigeonpea), vegetables (tomato/brinjal/bhindi), green fodder (chari), flower (marigold) and fruit plants (drumstick) were grown respectively in 33, 12, 2, 16, 10, 1 and 14% area. Twelve percent area of the farm devoted for construction of farm pond, shallow dug well and livestock shed. There is slight variability in land area for different enterprises in the six models which are related to variable supply of water. By adopting dry seeding technique with recommended package of practices, production of rice from 1/3rd area was nearly equal to that of a rainfed rice farmer harvesting from entire area of the farm. All the models are superior to traditional rainfed rice farming in the state in relation to total production, generation of employment and income from the farm. Adoption of improved techniques and increased availability of water for supplemental irrigation are helpful in enhancing the productivity and cropping intensity of the models compared to traditional farming. Inclusion of shallow dug well with farm pond enhanced the assurance of water availability in the farm for growing fodder crop during summer season as green fodder to the livestock. Fruit (drumstick) and flowers (marigold), fish, milk, meat and eggs were available for selling and earning cash round – the - year. All the farming system models were found promising for sustaining productivity and income of rainfed rice farms of the state. Farm level testing is underway for wide adoption after farmer's acceptable modifications.

RF 303 083 4026:Capacity building of Operational Research Project in Rainfed Agroecosystem: An Action Research (G. Ravindra Chary, Central Research Institute for Dryland Agriculture, Hyderabad)

The project started in January 2005 with the objectives of redefining the concept of ORP in the changing scenario of rainfed Agriculture; building the capacity of ORP for meeting the changing needs of integrating NRM research and livelihood issues and institutionalizing a process to enhance the effectiveness of ORP. The activity milestones during the first year (2005-06) were: Sensitisation Phase (Initiation workshop to sensitize ORP Scientists on the need to add value in terms of content and capacity to the ORPs); Consultation and Modification Phase (Technical workshop for consultations with experts, modification of technical program of ORPs). The project involves study areas of 8 operational research projects in AICRPDA network viz., Anantapur, Arjia, Ballowal-Saunkhri, Bangalore, Hisar, Indore, Ranchi, Solapur and the scientists from CRIDA, AICRPDA project coordination unit and from the main centers. During the sensitization phase, **initial feedback was** obtained from the network centers regarding revitalizing ORP's in terms of objective and focus, linkage between main center and ORP, stabilizing yields in ORP areas, farming system research, capacity building needs of the ORP scientists etc. This initial feed back was discussed during the sensitization workshop held on 20th October 2005 at CRIDA wherein the scientists from 8 ORP's and the respective main centers were involved. Many suggestions emerged during this session focusing on

technological issues (remandating ORP's, a paradigm shift to Farming Systems Research etc.), financial issues, infrastructure issues, policy issues (WTO, sociological consequences of ORPs etc.), HRD (31 key & theme areas have been identified for the scientists), Institutional issues and strengthening of ORPs with multidisciplinary scientific and technical staff. In continuation to this during Consultation and Modification Phase, a two day Technical Workshop was organized at CRIDA during 17-18 February, 2006 with the objectives of getting the scientists of 8 ORP's and respective main centers to appreciate the vital link between the AICRPDA center and the ORP attached to it; to inculcate a new line of thinking to enhance the effectiveness of ORP and to agree to include in the technical program at least one activity to integrate NRM issues to enhance livelihoods of small and marginal farmers in the rainfed agro eco system. The workshop adopted an ***'open agenda'*** to evolve a methodology to facilitate deliberations. Experts from previous experiments in ORP's and other disciplines facilitated the deliberations particularly on the subject of remandating ORP's and rainfed agriculture. New ideas such as, integration of natural resources for better rural livelihoods and institutional innovation for supporting technical adoption, need to give more emphasis on research towards supporting systems that aid adoption and diffusion of rainfed agriculture technologies were discussed and further highlighted how to bring in the policy research issues in ORP's. The outcomes of the discussions were: ORP's mandate should be facilitating technology development, adoption and diffusion process as relevant today and as envisaged in the inception of ORP's, more linkage between AICRPDA main center and ORP to work and develop as environment where both ORP and AICRPDA can play roles that are complementary to one another's objective but not competitive. ORP scientists were facilitated to evolve a simple method to assess the adoption and diffusion on 3 categories of technology viz., 1. technology that are adopted by ORP farmers and diffused to other farmers, 2. technology adopted by ORP farmers but not diffused to other farmers, 3. technology that are not adopted by either by ORP farmers or by others. Across 8 ORP's for the category 1 there were 9 technologies on *in-situ* moisture conservation, for category 2 -1and category 3-6; on rainwater management in category 1-7, category 2-3 and category 3-2; for varieties in category 1-85, category 2-3, category 3-nil; for other crop management practices in category 1-11, category 2-2, category 3-4; for cropping systems in category 1-8, category 2-8, category 3-1; for farm machinery in category 1-18, category 2-16, category 3-2; for INM in category 1-9, category 2-5, category 3-nil; for weed management in category 1-5, category 2-nil, category 3-1; for ALU in category 1-4, category 2-5, category 3-4; for farming systems in category 1 and 3- nil, category 2-2. In total there were 166 technologies for category 1 out which 85 related to different crop varieties followed by IMC (19) and farm machinery (18). There were 45 technologies for category 2 out of which 16 related to farm machinery followed by cropping systems (8). In category 3 there were 20 technologies out of which 6 related to *in-situ* moisture conservation followed by other practices (4) and alternate land use systems (4). Follow up to this exercise, the scientists from ORP's and main centers better appreciated the integration of NRM for better rural livelihoods and institutional innovation for supporting technology adoption and also the need for implementing the capacity of ORP to increase its effectiveness.

RF 303 083 4027: Ways to improve the agronomic efficiency of Phosphatic fertilizers in Vertisols of Chattisgarh (S.K.Sarwagi, Indira Gandhi Agricultural University, Raipur)

A series of field experiments were conducted on soybean-wheat and rice-chickpea cropping systems during kharif and rabi season in vertisols of Chattisgarh plains with the objective to increase the efficiency and utilization of native and applied phosphatic fertilizers. ***Soybean-Wheat Cropping System:*** Maximum yield of soybean was noticed at 60 kg P_2O_5 ha^{-1} (2660 kg ha^{-1}) which was on par with 30 kg P_2O_5 +PSB + RI (2560 kg ha^{-1}). Net profit (Rs.21425 ha^{-1}), B:C ratio, EUE and energy output: input ratio were also higher at 60 kg P_2O_5 ha^{-1} followed by 30 kg P_2O_5 +PSB +RI +VAM. Higher wheat yield (3480 kg ha^{-1}) and maximum net profit (Rs.22192) was recorded at the residual effect of 30 kg P_2O_5 + PSB + RI + VAM followed by 60 kg P_2O_5 ha^{-1} (3230 kg ha^{-1}) and 30 kg P_2O_5 + PSB + VAM (3.09 t) compared to control. The highest FP, AEP and REP were recorded at 30 kg P_2O_5 + PSB + RI + VAM for both the crops, whereas PEP was maximum at 60 kg P_2O_5 ha^{-1} followed by 30 kg P_2O_5 + PSB + VAM for soybean and at 30 kg P_2O_5 + VAM for wheat. Maximum build up of available N was recorded at 30 kg P_2O_5 + PSB +RI + VAM during both the seasons. Solubilization of active P also recorded the maximum at 30 kg P_2O_5 + PSB +RI + VAM followed by 30 kg P_2O_5 + PSB + VAM, whereas it decreased with increasing direct levels of P. The mean relative abundance of inorganic-P fraction followed the order Ca-P>Al-P>red. Sol.-P>Fe-P>Saloid-P after soybean and Ca-P>Fe-P reductant soluble –P>Al-P>Saloid-P after wheat crop. The availability of different fractions were enhanced with the application of PSB and VAM over respective levels of P. Yield, net profit, B:C ratio, maximum available N and solubilization of applied and native P were higher when P was blended with FYM (1:4) and applied in two splits (50% basal+50% 30 DAS) in both the crops. Total output energy, EUE and energy output: input ratio were higher under two split application of P alone and its residual effect on wheat was higher at three split application. Return per rupee investment on P fertilizer was higher under drilling application in soybean and under two split application after blending with FYM in wheat. Side placement or band placement in case of split application of P was found to be the best method of application or it should be placed close to the seed. Effect of P was more pronounced when combined with N, K and organic matter. Grain yield in soybean, economics, energy,

FP, AEP, REP, N status after soybean and solubilization of native P in residual effect of wheat were found to be higher under balance levels of nutrients combined with FYM. At 15 cm depth after soybean the order of predominant fractions were Ca-P>red.sol.-P>Fe-P>Saloid-P>Al-P, whereas it is Ca-P>Fe-P>red.sol-P>Al-P>saloid-P in wheat. ***Rice-Chickpea Cropping System:*** Significant higher grain yield, net profit, B:C ratio, EUE, energy output : input ratio, status of available N at both the depths and available –P at 0-15 cm, N and P uptake by crop were obtained in RS3 (where VAM culture was inoculated during nursery at the time of sowing) followed by rice seedling roots inoculated with PSB solution culture for half an hours which was on par with RS2 (where roots were incubated with ammonium citrate solution). But their residual effect could not improve the yield of chickpea significantly. VAM inoculated during nursery enhanced the Al-P (both depths), reductant soluble-P and Ca-P at 15-30 cm in rice and its residual effect on chickpea showed increased inorganic P at both the depths. However Fe-P at both depths and Ca-P at 0-15cm depth increased when rice roots were inoculated with PSB. 30+30 kg P_2O_5 ha^{-1}applied through SSP+RP enhanced the yield and its attributes, net profit, B:C ratio, EUE, energy output:input ratio, status of N and P in soil rhizosphere, content and uptake of N and P in crop in both the seasons. Whereas maximum solubilization of native P was recorded under 30 kg P_2O_5 applied thro RP. Maximum values of saloid bound-P, Al-P, Fe-P and reductant soluble-P were recorded at 60 kg P_2O_5 ha^{-1}applied thro RP. Ca-P was maximum under combined use of SSP-RP. However the residual effect of combined use of different sources of P at both the depths increased Saloid-P, Al-P, FE-P, Ca-P and total-P.

RF 303 083 4028: Relevance of micronutrient management in enhancing the productivity of cereal-pulse based production systems for alfisols of Karnataka (M. A. Sankar, University of Agricultural Sciences, Bangalore)

Soil application of $ZnSO_4$ @12.5 kg/ha +Borax 10kg/ha along with Mo @ 2 g/kg of seed gave higher grain yield of Greengram (490 kg/ha), Groundnut (1070 kg/ha), pigeonpea (1260 kg/ha), Cowpea (1072 kg/ha), Soybean (1207 kg/ha), and sunflower (920 kg/ha), while for finger millet and castor, it was application of $ZnSO_4$ @12.5 kg/ha and Borax @ 10 kg/ha (25.2 q/ha and 6.6 q/ha, respectively) Beside there was an overall improvement in soil micro flora and soil enzymatic activity due to use of micronutrients.

Cropping system: Application of NPK+$ZnSO_4$ @12.5 kg/ha +Borax @10 kg/ha +PSM +Rhizobium + VAM to fingermillet-pigeonpea cropping system recorded significantly higher grain yield (2010 kg/ha) of fingermillet as compared to other treatments and application of NPK + $ZnSO_4$ @ 12.5 kg/ha + PSM + Rhizobium + VAM to pigeonpea-fingermillet recorded significantly higher seed yield (984 kg/ha) of pigeonpea over application of only NPK (Control). Groundnut-Pigeonpea (8:2): Application of NPK along with combined foliar spray of $ZnSO_4$ @ 0.5% + Borax @ 0.25% to both intercrop as well as main crop in groundnut-pigeonpea (8:2 intercropping system), gave higher groundnut equivalent yield (805.4 and 743.6 kg/ha, respectively) compared to application of only NPK (Control). Fingermillet – Pigeonpea (8:2): Application of NPK along with combined foliar spray of $ZnSO_4$ @ 0.5% + Borax @ 0.25% to both intercrop as well as pigeonpea crop in fingermillet – pigeonpea (8:2 intercropping system), gave higher fingermillet equivalent yield (1296 and 1167 kg/ha, respectively) as compared to application of only NPK (Control).

RF 303 083 4029: Identifying high yielding genotypes of sesame with short duration for the Eastern Dry Zone of Karnataka (A. Manjunath, University of Agricultural Sciences, Bangalore)

Preliminary screening of sesame genotypes for early and late *kharif* seasons: During first year of the project, 50 entries were evaluated for early *kharif* and 60 entries for late *kharif*. From these experiments, based on their relative yield performance and farmers' preference, 26 and 20 entries were selected for early and late *kharif* respectively and were promoted to IYT for respective seasons of the subsequent year i.e. second year of the study. *Initial yield trial (IYT) of sesame genotypes for early kharif:* During second year, IYT were taken up in five locations successfully for early *kharif*. Based on farmers' selection and actual yields 14 entries *viz*., Ajjampura local, Chandana, Dhavari, Dinnur local, E-8, Gouri, Savanur local-1, Savanur local-2, ST-6, ST-9(2), ST-11, Thilak Uma and YLM-17 have been identified as promising entries and promoted to Advanced yield trial (AYT) to be conducted over locations during third year for early *kharif* (2007-08) and finally to select the most promising entries for the Eastern Dry Zone of Karnataka as a whole or each farming situation separately for early *kharif* cultivation and the work is in progress. I*nitial yield trial (IYT) of sesame genotypes for late kharif* : Similarly, 20 entries *viz.*, Chandana, Dinnur local, DS-1, E-8, HT-1, Rama, Ranibennur local, ST-3, ST-5, ST-6, ST-7, ST-9(1), ST-9(2), ST-11, ST-14, Swetha til, Thali local, Turuvekere black and Uma have been selected finally for late *kharif* cultivation for the Eastern Dry Zone of Karnataka and the work is in progress.

RF 303 083 4030: Strengthening and evaluation of on-farm farming system models in relation to farm productivity, soil health, economic sustainability and employment generation in Southern Dry Zone of Karnataka (H. R. Shiva Kumar, University of Agricultural Sciences, Bangalore)

Based on the existing factors (resources, size of holdings, enterprises practiced, crop grown and others) the farming systems were strengthened and evaluated for various combination models *viz.*, crop production + dairy, crop production + fodder + dairy, crop production +vegetables

+dairy, crop production + sheep/goat + dairy +sericulture, crop production + sheep/goat +dairy + sericulture +poultry, crop production + sheep/goat +dairy + sericulture + piggery. All the above systems were evaluated for their productivity, potentiality, economic sustainability in relation to effective recycling of farm wastes and livelihood of the social elements. Training programmes, Field days and Animal health camps were conducted in collaboration with line departments and NGO's in order to bring out the relevance of farming system to farmers in enhancing the economic returns besides conserving natural resources through effective recycling and employment generation. Integration of small ruminants sustained the poor farmer's from drought and unforeseen calamities as they serve as All Time Money (ATM) cards. Strengthening of weak and missing links in crops and animal husbandry is an ideal tool to generate the income for the small and marginal farmers. Further, it has been proved beyond doubt that strengthening of women groups in natural resource management helps in sustaining the farm income. Indeed, the mass programmes like animal health camp, mass training to farmers with new technology is highly beneficial and payable in a long run.

RF 303 083 4031: Assessing soil quality key indicators for development of integrated soil quality under predominant management practices in rainfed agro-ecology (K.L. Sharma, Central Research Institute for Dryland Agriculture, Hyderabad)

Soil quality is defined as the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation. In order to see the long-term effects of predominant management practices on soil quality and to delineate the best aggradative management practices, long-term ongoing experiments at Anantapur (Alfisol), Phulbhani (Oxisol/ Alfisol), Akola (Vertisol), Ranchi (Oxisol), Dantiwada (Entisols) and Bijapur (Vertisols) were chosen. Soil quality was monitored by computing Relative Soil Quality Index (RSQI) using chemical indicators (for Anantapur and Phulbani) and physical, chemical and biological soil quality indicators for other centres. The salient findings were as follows: **Anantapur center:** At Anantapur, in groundnut crop, most of the soil quality parameters were significantly influenced by application of long-term nutrient management treatments. There was considerable build up of available P and Zn in management treatments when compared with control. The highest amount of P (67.88 kg ha^{-1}) was recorded in treatment which received inorganic fertilizer doses @ 20-40-40 kg NPK (T2) followed by T2 + $ZnSO_4$ @ 50 kg/ha (54.55 kg P ha^{-1}). Highest amount (4.7 g kg^{-1}) of organic C was recorded in application of FYM @4 t ha^{-1} followed by 10-20-20-NPK kg ha^{-1} + FYM 4 t ha^{-1}, (4.1 g kg^{-1}). Similarly, Zn content was found as high as 9.30 mg g^{-1} and 5.11 mg g^{-1} in T2+$ZnSO_4$ and FYM applied @ 4 t ha^{-1} respectively. The relative soil quality index (RSQI) across the treatments varied from 0.63 to 1.00 with the highest RSQI (1.00) in 10-20-20- NPK kg/ha + FYM 4t/ha followed by 20-40 -40 NPK kg/ha + $ZnSO_4$ @ 50 kg/ha (T5) (0.99) and 20-40-40 NPK kg/ha + G. nutshells @ 4 t/ha (T6) (0.99). In tillage experiment with groundnut as the test crop, the RSQI varied form 0.36 to 1.00. Among all the treatments, Low tillage + 100 % organic treatment had the highest RSQI of 1.00 while the other treatment combinations viz., Low tillage + 50 % organic + 50% inorganic (0.98), Conventional tillage + 50 % organic + 50 % inorganic (0.98) and LT + herbicide+ 100 % organic (0.98) were found to be on par from the viewpoint of soil aggradation. In castor -groundnut rotation at Anantapur, RSQI varied from 0.53 to 1.00, the highest being in 50% N (glyricidia) + 50% N (inorganic) followed by 100% N inorganic (0.75). **Phulbani centre:** At Phulbani, in Rice– Horse gram system, organic C content was found highest (5.2 g kg^{-1}) in 50% RDF + 50% FYM followed by 50% RDF + 50% RDF (Glyricidia) (4.1 g kg^{-1}) and 50% RDF + 50% RDF (Cassia) (4.1 g kg^{-1}). The RSQI values in this experiment ranged from 0.53 (100% RDF) to 1.0 (50% RDF + 50% FYM). In Pigeonpea + rice system at Phulbani, Zinc content maintained by management treatments was almost above general critical limit (0.6 mg g^{-1}). The treatments which maintained RSQI more than 0.80 were: 30 N (GL) +15 N (CF) (1.00), 20 N (GL) +25 N (CF) (0.82), 20 N (FYM) +25 N (CF) (0.82), 30N (FYM) +15N (CF) (0.88) and Organic (GL) 45 Kg (0.82) and were found to be aggregative in nature. In rainfed kharif rice at Phulbani, the RSQI varied from 0.55 in 25kg N (FYM) to 1.00 in (15 kg N (FYM) + 20 Kg N (inorg.). Combination of 15kg N (FYM) + 10 kg N (GL) resulted in RSQI value of 0.70. In Yam +maize system at Phulbani, most of the treatments almost tended to aggrade the soil quality with RSQI varying from 0.57 to 1.0, the highest RSQI being in 50 % (CF) + 50 % N (GL), followed by 100% RDF (CF) (80:60:80 N-P_2O_5-K_2O ha^{-1}) (0.70). Frequent cultivation of soils for fine tilth breaks the soil aggregates and promotes fast oxidation of even entrapped organic matter in micro-aggregates. Reduced tillage coupled with recycling of residue forms one of the important practices of conservation agriculture. In tillage experiment, RSQI varied from 0.56 (LT+ interculture+ herbicide +100% inorganic) to 1.0 (CT+ Interculture+ 100 % organic). Other equally important aggrading treatments were found to be LT+ Interculture+ herbicide +100% organic (0.98), LT+ interculture+ herbicide +50% inorganic +50 % organic (0.88) and CT+ Interculture +50% inorganic +50 % organic (0.87). Interestingly, in farmers field, highest amount (7.7 g kg^{-1} soil) of organic C was found in maize + pigeonpea system followed by maize + toria system (7.2 g kg^{-1} soil). Soils were low in available N and low to medium in available P while K content was considerably higher. Sulphur content in farmers field was considerably low and need to be seriously looked into especially in case of oil seed crops. However, micronutrient content was found adequate. The toxicity of Mn and its antagonistic effect if any, needs to be tracked as and when

required. RSQI varied from 0.79 in Turmeric to 1.0 in Maize +Toria system. From this data set, it appears that the level of management in farmers field was quite encouraging and aggrading. The data on RSQI will be updated in all the situations discussed above after generating data on some more soil quality indicators. **Akola Centre:** In integrated nutrient management studies in cotton + green gram intercropping at Akola, barring calcium and iron, most of the soil chemical health indicators were found to be significantly influenced by soil nutrient management treatments. Among all the INM treatments, use of 25 kg P_2O_5 ha^{-1} + 50 kg N ha^{-1} through leuceana proved superior most in soil chemical / fertility indicators such as organic carbon, available N, P and K. Among the micronutrients, Mn, Zn, Cu and B were significantly influenced by the management treatments. Among the biological parameters, highest microbial biomass carbon (142.85 mg g^{-1} soil) and labile carbon (215.82 mg kg^{-1}) were recorded in 25 kg P_2O_5 ha^{-1} + 50 kg N ha^{-1} through leuceana. Application of 25 kg N ha^{-1} through FYM played an important role in improving the physical soil quality indicator viz., mean weight diameter to the extent of 0.36 mm, which was followed by 25 kg N + 25 kg P_2O_5 ha^{-1} + 25 kg N ha^{-1} through FYM (0.35 mm). The Relative Soil Quality Index (RSQI) of these soils across the management treatments varied from 0.52 to 1.00. The order of decrease in the magnitude of relative soil quality index of the integrated soil nutrient management treatments was as follows: 25 kg P_2O_5 ha^{-1} + 50 kg N ha^{-1} through leuceana (1.00) > 25 kg N + 25 kg P_2O_5 + 25 kg N ha^{-1} through FYM (0.96) > 50 kg N + 25 kg P_2O_5 ha^{-1} (0.75) > 25 kg N ha^{-1} through FYM (0.63) >25 kg N ha^{-1} through leuceana (0.52). Hence, in comparison to other treatments practiced, 25 kg P_2O_5 ha^{-1} + 50 kg N ha^{-1} through leuceana was found most superior. **Ranchi Centre:** In an experiment on integrated nutrient supply system for rainfed-semi-arid tropics under rice – black gram rotation at Ranchi, highest organic carbon content was recorded in 15 kg N compost + 20 kg N inorganic (6.3 g kg^{-1}). Except N, P, Mg and Mn, all the chemical soil quality parameters were significantly influenced by nutrient management treatments. Available K content was highest under 25 kg N through compost (156.3 kg ha^{-1}). The iron content in the experimental plots was quite high and varied from 14.9 to 21.3 mg g^{-1} of soil. Toxicity of Fe or nutrient imbalance caused due to its excess need to be tracked through visual crop symptoms, whenever needed. Among the biological indicators, dehydrogenase activity (DHA) and microbial biomass carbon were found to be significant due to nutrient management treatments. DHA was found to be highest under 15 kg N Green leaf + 10 kg N inorganic (4.16 mg TPF hr^{-1} g^{-1} soil) and 15 kg N Green leaf + 20 kg N inorganic (4.15 mg TPF hr^{-1} g^{-1} soil). Treatments also played an important role in soil aggradation by significantly influencing the physical indicators such as bulk density and mean weight diameter. Bulk density was found to be lowest with 15 kg N Green leaf + 20 kg N inorganic (1.22 Mg m^{-3}). Relative soil quality index ranged from 0.59 to 1.00. From the view point of soil aggradation and relative soil quality index, the performance of soil nutrient management treatment was: 15 kg N compost + 20 kg N inorganic (1.00) > 15 kg N Green leaf + 20 kg N inorganic (0.98) > 100% Rec N (40 kg through inorganic) (0.93) > 15 kg N Green leaf + 10 kg N inorganic (0.83) > 25 kg N through Compost (0.72) > 15 kg N compost + 10 kg N inorganic (0.62) > 50% Rec N (Inorganic) (0.59). Thus, among all the treatments practiced, 15 kg N compost + 20 kg N inorganic treatment was found to be most aggradative with highest RSQI. In another long-term tillage and nutrient management experiment with rice (B.G. 23-19) as a test crop at Ranchi, the results indicated that, among all the soil quality indicators, organic carbon, dehydrogenase assay and microbial biomass carbon were found to be significantly influenced by the tillage and nutrient management treatments. Relative soil quality index (RSQI) of nine management treatments varied from 0.48 to 1.00. The relative order of aggradation of the treatments was as follows: LT+ weedicide + 1 hand weeding + FYM 4 t ha^{-1} (Compost)+20:15:10 kg NPK ha^{-1} (1.00) > LT+ weedicide + 1 Hand weeding + FYM 8 t ha^{-1} (Compost) (0.92) > LT+ 2 Hand weedings + FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} (0.91) > LT+ 2 Hand weedings + FYM 8 t ha^{-1} (Compost) (0.86) > CT+ 2 Hand weedings + FYM 8 t ha^{-1} (Compost) (0.79) > CT+ 2 Hand weedings+40:30:20 kg NPK ha^{-1} (0.71) > LT+ weedicide + 1 hand weeding + 40:30:20 kg NPK ha^{-1} (0.68) > CT+ 2 Hand weedings + FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} (0.67) > LT+ 2 Hand weedings + 40:30:20 kg NPK ha^{-1} (0.48). **S.K.Nagar Centre:** At Dantiwada, among the INM treatment combinations applied to pearlmillet evaluated for soil quality, Relative soil quality index for the management treatments varied from 0.44 (50% Recommended dose of nitrogen through urea) to 1.00 (50% RDN (urea) + 50% RDN (FYM). From the viewpoint of aggradation of soil quality: 50 % RDN (urea) + 50% RDN (FYM) (1.00) > 50 % RDN through FYM (0.95) > Farmers method 5 t FYM ha^{-1} (once in three years) (0.82) > 100 % RDN through urea (0.78) > 50 % RDN through urea (0.44). The conjunctive use of 50% RDN (urea) + 50% RDN (FYM) was found superior most. Interestingly, the practice of application of 5 t FYM ha^{-1} (once in three years; Farmers method) also maintained good relative soil quality index. The present study on assessment of soil quality of INM practices would be helpful in identifying one or two very important INM approaches for the targeted region. It would also help in reducing the workload of researchers to spend precious time on experimenting number of combinations of INM. Instead the focus can go on to transfer of technology of the practice directly to the farming community. **Bijapur Centre:** At Bijapur, two sets of treatments have been evaluated for soil quality and their aggrading and degrading behaviour. In the first set, the order of aggradation was 50% RDF + 15 kg ha^{-1} $ZnSO_4$ (1.00) > 50% N (FYM) (0.97) > 50: 25:0 kg ha^{-1} RDF (Sorghum) - 37.5:50:15 kg ha^{-1} RDF (Safflower) (0.84) > 50 % N sunhemp (0.76). Application of 50% RDF + 15 kg ha^{-1} $ZnSO_4$ to sorghum and

safflower was found superior most. This probably is attributed to supplementation of sulphur and zinc to the soil. In another set of treatments applied to rabi sorghum, application of 15 kg N (compost) + 10 kg N (sunhemp) (RSQI 1.00) was found most promising. The second best option could be 15 kg N (compost) + 20 kg N (inorganic) (0.861) followed by application of 100% N through urea (0.778). Based on the relative soil quality index, the general ranking was 15 kg N (compost) + 10 kg N (sunhemp) (1.00) > 15 kg N (compost) + 20 kg N (inorg) (0.86) > 100% N urea (0.78) > 25 kg N compost (0.64) > 15 kg N (sunhemp) + 20 kg N (inorg) (0.62). While computing RSQI, available nitrogen has been observed as a serious constraint. If this was the condition observed in the experimental plots, the condition in farmer's fields could be even more pathetic. Focused efforts need to be made for improving organic carbon and nitrogen availability in these soils for getting higher yields of rabi sorghum.

RF 303 083 4032: Integrated nutrient management in pigeonpea based intercropping systems under rainfed condition (Arjun Sharma, University of Agricultural Sciences, Dharwad)

The studies indicated that pigeonpea intercropped with green gram (1:2) recorded significantly higher pigeonpea seed yield (1551 kg/ha) compared to the pigeonpea intercropped with pearl millet in 1:2 ratio (1500 kg/ha). Among INM treatments, application of vermicompost @ 2 t/ha + Recommended Dose of Fertilizer (RDF) to pigeonpea and green gram recorded highest grain yield of pigeonpea (1816 kg/ha), followed by phospho compost @ 2.5 t/ha + 50% RDF to pigeonpea and green gram (1723kg/ha), which was on par with FYM @ 5 t/ha +50% RDF (1685 kg/ha) in pigeonpea + green gram system. Similar trends of results was observed with application of organic manures in combination with fertilizer levels in pigeonpea + pearlmillet intercropping systems. Pigeonpea + green gram (1:2) with phospho compost @ 2.5 t/ha + 50% RDF recorded highest B:C ratio (3.93) with net income of Rs 32,766/ha followed by FYM @ 5t/ha + 50% RDF (3.68). Similarly, use of vermicompost @ 2.5t/ha + 50% RDF to pigeonpea + pearl millet system recorded highest net returns (Rs 33,325/ha) with B:C ratio of 3.30. In respect of crop residues, incorporation of pigeonpea stalks @ 5t/ha + 100% RDF gave highest seed yield of pigeonpea (1523kg/ha) in pigeonpea and green gram system. This combination was on par with sorghum stubbles @ 5t/ha along with 100% RDF (1505 kg/ha), sunflower stalks @ 5 t/ha +100% RDF (1485 kg/ha) and pigeonpea stalks @ 5 t/ha with 50 % RDF (1473 kg/ha). Similar trends of results were observed with crop residues with varied fertilizer levels in pigeonpea + pearl millet intercropping systems. Application of pigeonpea stalks 5 t/ha with 100% RDF registered highest B:C ratio (3.38) followed pigeonpea stalks @ 5 t/ha +50% RDF (3.35) in pigeon pea + green gram (1:2) system (3.35). In another study, pigeonpea + green gram (1:2) with FYM @ 5 t/ha + 50% RDF along with seed inoculation with biofertilizers registered highest B:C ratio (4.09), followed by 50% RDF with seed inoculation of biofertilizers (4.05). Thus integration of chemical, organic and biological sources with efficient management not only sustained productivity and soil health but also reduced the cost of chemical fertilizers in different rainfed crops and cropping systems.

7. Publications

AICRPDA Coordinating Cell
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AICRPDA Centers

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8. Project Team of AICRPDA

CRIDA	Name & Address
Director, CRIDA	Y.S. Ramakrishna (O) 040-24532262 (R) 040-24532262 Fax: 040-24531802 E-mail: ramakrishna.ys@crida.ernet.in
AICRPDA Project Coordination Unit	
Project Coordinator (Dryland)	K.P.R. Vittal (upto 28th Dec'06) G. Subba Reddy (from 29th Dec'06 till date) (O) 040-24530828 (R) 040-24045758 Fax : 040-24530828 E mail : pc-dryland@crida.ernet.in
Principal Scientist (Agril. Statistics)	G.R. Maruthi Sankar (O) 040-24530828 (R) 040-24078801 Fax : 040-24530828 E mail : gmsankar@crida.ernet.in
Senior Scientist (Agronomy)	G. Ravindra Chary (O) 040-24530828, (R) 040-24546884 Fax : 040-24530828 E mail : rcgajjala@crida.ernet.in

CRIDA	Name & Address
Technical Staff	
Technical Officer T-6 (Computers)	A. Girija (O) 040-24530828 (R) 040-27668491 (M) 9849044027 E mail : agirija@crida.ernet.in
Technical Officer T-6 (Agricultural.Economics)	RVVSGK. Raju (O) 040-24530828. (R) 040-24030506 (M) 9866870662 E mail : rajurk@crida.ernet.in
Technical Officer T-5	L. Sree Ramulu
Administrative staff	
Asst. Admn. Officer	A. Premakumari O) 040-24530828, (R) 040-24146105 (M) 9989433358 E mail : prema@crida.ernet.in
Personal Secretary	G. Varalakshmi O) 040-24530828, (R) 040-24203582 (M) 9441118980 E mail : gvlakshmi@crida.ernet.in
SSG-3	N. Manikya Rao

Production System/Center	Name of the staff & Address
Rice based production system	
JAGDALPUR	S.K. Patil Chief Scientist AICRP for Dryland Agriculture Bastar, Shaheed Gundadhur College of Agriculture & Research Station Kumhrawand, Jagdalpur Chattisgarh Tel: (O)07782-229360, (R) 229343 Email: spatil-igau@yahoo.com
JORHAT	R.M. Karmakar, Chief Scientist Dryland Agriculture AICRP for Department of Soil Science, AAU Jorhat, Assam Tel(O): 0376-2340814, (R) 2340944 Fax:0376-2310831,2340001 Email: rmkarmakar@aau.ac.in
FAIZABAD	Bhagwan Singh, Chief Scientist Shivakant, Soil *Physicist* AICRP for Dryland Agriculture Department of Agronomy, Narendra Deva university of Agriculture & Technology, Faizabad – 224 229, Uttar Pradesh Tel: (O) 05270 –262066 (R) 265824 Email:bhagwansingh@nduat.ernet.in

Production System/Center	Name of the staff & Address
RANCHI	D.N. Singh, Chief Scientist AICRP for Dryland Agriculture Birsa Agricultural university, Kanke, Ranchi – 834 006, Jharkhand Tel: (O) 0651 – 2450839 FAX: 0651 – 2450850 Email: bau@bitsmark.com
PHULBANI	B. Behera, Chief Scientist A.K. Pal, Soil Physicist C.R. Subudhi, Agril. Engineer A.K.Mishra, Plant Breeder AICRP for Dryland Agriculture Old TAR building, Madikunda Chowk, Orissa University of Agriculture and Technology, Phulbani – 762 001, Orissa Tel: (O) 06842 – 253750, (R) 254670 FAX: 06842 – 253773 (pp) Email:Email:csdlapphulbani@rediffmail.com
VARANASI	S.R. Singh, Chief Scientist T.Y. Singh, Agril. Engineer R.P. Singh, Agronomist J.P. Lal, Plant Breeder AICRP for Dryland Agriculture

Production System/Center	Name of the staff & Address
	Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi – 221 005, Uttar Pradesh Tel: (O) 0542 – 2307111, (R) 2318274 (M) 09415812143 FAX: 0542 – 2368174, 2368993
Maize based production system	
ARJIA	P.M. Jain, Chief Scientist S.N. Soddani, Plant Breeder M.L. Jat, Agril. Engineer B.L. Nagda, Agronomist AICRP for Dryland Agriculture Agriculture Research Station, Dryland Farming Research Station, Maharana Pratap University of Agriculture and Technology, P.B.NO.62 Arjia, Bhilwara – 311 001, Rajasthan Tel: (O) 01482 – 264073, (R) 01482-253130 FAX: 01482 – 220322
BALLOWAL SAUNKHRI	B.S. Sidhu, Chief Scientist Bharat Bhushan, Soil Physicist Saman Preeth Kaur, Jr. Agril. Engineer AICRP for Dryland Agriculture Regional Research Station for Kandi Area, Punjab Agricultural University, Ballowal Saunkhri, P.O.Takaria, via. Balachaur, *Dist. Ballowal Saunkhri*, Punjab – 144 521 Tel(O):01885-241601, (R) 01884-282102 Fax: 01885-241607
RAKH DHIANSAR	Mahendra Singh, Chief Scientist Vikas Abrol, Junior Soil Physicist J.P. Singh, Jr. Agril. Engineer AICRP for Dryland Agriculture Dryland Agriculture Research sub – station, Sher-E-Kashmir University of Agricultural Sciences and Technology, Rakh Dhiansar, Bari Brahmana, Jammu – 181 133 Tel: (O) 09123 –220821,(R) 2431585
Groundnut based production system	
ANANTAPUR	K. Srinivasa Reddy, Chief Scientist S. Vasundhara, Plant Breeder Vijaya Sankar Babu, Soil Physicist B. John Wesley, Agril.Engineer AICRP for Dryland Agriculture DCMS building, Kamalanagar, Agricultural Research Station, Acharya N.G.Ranga Agriculture University, Anantapur – 515 001, Andhra Pradesh Tel: (O) 08554 – 277618, FAX: 08554 – 277 633 Email:vijay7970@rediffmail.com

Production System/Center	Name of the staff & Address
RAJKOT	D.R. Padmani, Research Scientist M.S. Gajera, Agronomist M.D. Khanpara, Plant Breeder K.N. Akbari, Agril. Chemist G.R. Sharma, Agril. Engineer AICRP for Dryland Agriculture Main Dry Farming Research Station, Junagadh Agricultural university, AH & Post: Targhadia, Rajkot – 360 003, Gujarat. Tel: (O) 0281 – 2784260, (R) 2574558 Fax: 0281-2576934
Soybean based production system	
INDORE	S.K. Argal, Chief Scientist H.S. Thakur, Agronomist Indu Swaroop, Plant Breeder S.K. Sharma, Soil Physicist AICRP for Dryland Agriculture College of Agriculture, Jawaharlal Nehru Krishi Viswa Vidyalaya, Indore – 452 001 Madhya Pradesh Tel: (O) 0731 – 2701254, 2702911, (R) 0731 – 2710701 FAX: 0731 – 2496989
REWA	M.S. Bhagel, Chief Scientist D.P. Dubey, Agronomist G.P. Tembe, Soil Physicist S.K. Gupta, Agricultural Engineer A.K. Pandey, Agronomist AICRP for Dryland Agriculture, College of Agriculture, Rewa – 486 001, Madhya Pradesh Tel: (O) 07662 – 220628 FAX: 07662 – 220732 Dean: (O) 07662 – 220732 Associate Director of Research: (O) 07662 – 58508
Cotton based production system	
AKOLA	S.M. Patil, Chief Scientist B.N. Akhare, Agronomist S.B. Parde, Plant Breeder M.B. Nagdeve, Agril. Engineer S. Maulikar, Soil Scientist AICRP for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, AKOLA – 444 104, Maharashtra Tel: (O) 0724 – 2258569,(R) 2458712 Fax: 0724- 2258569
KOVILPATTI	K Subbiah, Chief Scientist U Solaiappan, Agronomist Gnanamallar, Plant Breeder D Jawahar, Soil Scientist M Rajeswari, Agril. Engineer AICRP for Dryland Agriculture Agricultural Research Station, Tamil Nadu Agricultural University, Kovilpatti – 628 501 Tuticorin dist, Tamil Nadu Tel: (O) 04632 – 220533 FAX: 04632 – 221133 Email:k_subbiah_tnau@yahoo.com

Production System/Center	Name of the staff & Address
PARBHANI	M.G. Lomte, Chief Scientist AICRP for Dryland Agriculture, Marathwada Agricultural University, Parbhani, Maharashtra
Sorghum based production system	
BELLARY	P.K. Mishra S.L. Patil Regional Station AICRP for Dryland Agriculture Central Soil and Water Conservation Research and Training Institute, Research Center, Bellary - 583 104, Karnataka Tel : (O) 08392-242164, 242665 (R) 242534, 08392-242665 Email: pkmbellary @ rediffmail.com soilcons1@rediffmail.com
BIJAPUR	M.B. Guled, Chief Scientist V.S. Surakod, Agronomist B.G. Prakash, Plant Breeder Sirhatti, Agril. Engineer Sarwad, Soil Scientist AICRP for Dryland Agriculture Agriculture Research Station, University of Agricultural Sciences (Dharwad), P.B.No.18, Bijapur – 596 101, Karnataka Tel: (O) 08352 – 267215, (R) 267217 FAX: 08352–267215 Email: surakod@hotmail.com
SOLAPUR	A.L. Pharande, Chief Scientist A.N. Deshpande, Soil Physicist P.B. Gawande, Plant Breeder Pachurne, Agril. Engineer Kathmale, Agronomist AICRP for Dryland Agriculture Mahatma Phule Krishi Vidyapeeth, "Krishak Bhavan", near D.A.V.College, P.B.No.207, Solapur – 413 002, Maharashtra Tel: (O) 0217 – 2373982 Email: spr_adrnarp@sancharnet.in
JHANSI	Niranjan R.K. Agarwal Crop Production Division AICRP for Dryland Agriculture IGFRI, Pahuj Dam, Jhansi - Gwalior Road, Jhansi - 284003, Uttar Pradesh. Tel: (O) 0517-2442446 (R) 0517-2447143, 0517-440908 igfri@400 x nic.up.in
Pearlmillet based production system	
AGRA	S.P.S. Chauhan, Chief Scientist S.P. Singh, Soil Physicist A.K. Nema, Jr. Agril. Engineer AICRP for Dryland Agriculture RBS College, Agra University, Bichpuri, AGRA – 283 105, Uttar Pradesh Tel: 0562 – 2636449 (Principal Office) (R) 0562-2570667, Fax: 0562-2636449
SARDAR KRUSHINAGAR	M.M. Patel, Chief Scientist J.J. Patel, Soil Physicist R.S. Singh, Agril. Engineer P.G. Patel, Agronomist AICRP for Dryland Agriculture, Regional Research Station, Dantiwada Agricultural University, Sardar Krishinagar – 385 506 Gujarat Tel: (O) 02748 – 278471/ 278435 P.S. Patel, Plant Breeder (R) 02748-278472 FAX: 02748 – 278433
HISAR	Milakh Raj, Chief Scientist R.S. Sangwan, Plant Breeder Sidhpuria, Agril. Engineer Veereswar Singh, Agronomist AICRP for Dryland Agriculture CCS Haryana Agricultural University, Hisar – 125 004, Haryana Tel: (O) 01662 –289263, (R) 244750 Ext.4268 FAX: 01662–234952 Email: dryland@hau.ernet.in
Fingermillet based production system	
BANGALORE	M.A. Shankar, Chief Scientist Indra Kumar, Agril.Engineer A. Manjunath, Plant Breeder G.N. Gajanana, Soil Physicist AICRP for Dryland Agriculture, University of Agricultural Sciences, G.K.V.K., Bangalore – 560 065, Karnataka Tel: (O) 080 – 23620795, 3330153, 3330348, (R) 23331539 FAX: 080 – 23620795 Email: shrungar@usanet
Operational Research Project	
ANANTAPUR	Y. Padmalatha, Agronomist K.Bhargavi, Junior Agronomist AICRP for Dryland Agriculture DCMS building, Kamalanagar, Agricultural Research Station, Acharya N.G.Ranga Agriculture University, Anantapur – 515 001, Andhra Pradesh Tel: (O) 08554 –257239(R) 274263 FAX: 08554 – 257239 Email: ypl_agro@hotmail.com
ARJIA	S.K. Sharma, Agronomist K. Kotaria, Agrl. Engineer K.C. Laddha, Soil Scientist AICRP for Dryland Agriculture Agriculture Research Station Dryland Farming Research Station, Maharana Pratap University of Agriculture and Technology, P.B.NO.62 Arjia,

Production System/Center	Name of the staff & Address
	Bhilwara – 311 001, Rajasthan Tel: (O) 01482 – 264073 FAX: 01482 – 238732
BANGALORE	Mari Raju, Agronomist B.S. Lingappa, Agronomist G.K.V.K., Ashok, Agril. Engineer AICRP for Dryland Agriculture, University of Agricultural Sciences, Bangalore – 560 065, Karnataka Tel: (O) 080 – 23620795, 3330153, 3330348 FAX: 080 – 23620795 Email: shrungar@usanet
BALLOWAL-SAUNKHRI	Sukhwinder Singh, Agronomist Parvinder Singh, Agronomist AICRP for Dryland Agriculture Regional Research Station for Kandi Area, Punjab Agricultural University, Ballowal Saunkhri, P.O.Takaria, via. Balachaur, Dist. Ballowal Saunkhri, Punjab – 144 521 Tel (O): 01885-241601, (R) 282102 Email: sukhagron@yahoo.com
INDORE	D.H. Ranade, Agril. Engineer M.C. Chourasia, Agronomist AICRP for Dryland Agriculture College of Agriculture, Jawaharlal Nehru Krishi Viswa Vidyalaya, Indore – 452 001 Madhya Pradesh Tel: (O) 0731 – 2701254, 2702911 (R) 0731–2702033 FAX: 0731–2496989 Email: dhranade@rediffmail.com

Production System/Center	Name of the staff & Address
HISAR	L.K. Midha, Agronomist P.S.Mallick, Agronomist V.S. Rana, Agronomist AICRP for Dryland Agriculture CCS Haryana Agricultural University, Hisar – 125 004, Haryana Tel: (O) 01662 –289263, 244308 Ext.4268 FAX: 01662 – 234952
RANCHI	Nargis Kumari, Jr.Agronomist Jab Mintoo, Jr. Agril. Engineer AICRP for Dryland Agriculture Birsa Agricultural university, Kanke, Ranchi – 834 006, Jharkhand Tel: (O) 0651 – 2455839 FAX: 0651 – 2455850 Email: bau@bitsmark.com
SOLAPUR	S.B. Surve, Agronomist S. Upadhyaya, Junior Scientist S.B. Thorve, Junior Agronomist AICRP for Dryland Agriculture Mahatma Phule Krishi Vidyapeeth, "Krishak Bhavan", near D.A.V.College, P.B.No.207, Solapur – 413 002, Maharashtra Tel: (O) 0217-237329, (R) 2374553 Fax: 0217 – 2373982 Email: spr_adrnarp@sancharnet.in

9. Budget utilization of network centers of AICRPDA (2005-06)

Centre	Opening Balance	Remitt-ance	Reve-nue Receipt	Pay & Allow.	T.A.	R.C.	N.R.C.	I.T.	On Farm Trials	Centre of su-pport	Total	Closing balance
AKOLA(MC)	1147325	3720000	0	2743112	8126	265255	45207	0	0	0	3061700	1805625
ANANTAPUR(MC)	1871334	3700000	4224	2104619	27787	224957	48357	0	0	0	2405720	3169838
ARJIA(MC)	75931	3700000	0	2607681	47300	223776	385154	0	0	0	3263911	512021
B.SAUNKHRI(MC)	524044	3700000	0	2987121	36729	224942	336505	30980	0	0	3616277	607767
BANGALORE(MC)	2786291	3951000	0	3222879	41052	224992	138885	49895	0	275039	3952742	2784549
BIJAPUR(MC)	-222327	3925000	0	2896133	37358	339767	8611	0	0	0	3281869	420804
S.K.NAGAR(MC)	1920376	3700000	42109	3132538	46333	338478	215444				3732793	1929692
HISAR(MC)	4084632	3900000	0	2629156	42002	223816	509552	61995	0		3466521	4518111
INDORE(MC)	684223	3700000	0	2706092	37444	224987	0	0	0	0	2968523	1415700
JAGDALPUR(MC)-NEW	1431723	1900000	0	2186782	37466	224091	561347	0			3009686	322037
JORHAT(MC)-NEW	1577568	3900000	0	2042630	54770	117270	467978	88566	0	0	2771214	2706354
KOVILPATTI(MC)	272967	3700000	0	2997592	48417	222164	491200	13376	64244	0	3836993	135974
PARBHANI(MC)-NEW	896282	3900000	0	2377706	24128	236684		0	0	0	2638518	2157764
PHULBANI(MC)	755518	3700000	0	2193541	37431	175874	265874	18000	0		2690720	1764798
RANCHI(MC)	1005327	3700000	0	2100000	10000	102000	157000	116000	0	0	2485000	2220327
REWA(MC)	836316	3700000	0	2622708	37423	274687	0	0	0	0	2934818	1601498
TARGHADIA(MC)	1557396	4004000	55428	3029468	95405	569332	164081	0	0	0	3858287	1758537
SOLAPUR(MC)	3412764	3800000	0	2956710	36097	275010	508964	42797	0	1086627	4906205	2306559
VARANASI(MC)	4428734	4700000	0	5359745	46604	410302	0	0	0	2423545	8240196	888538
AGRA(SC)	1306486	3800000	33674	2583977	33844	182255	735801	44420	33674	0	3613971	1526189
FAIZABAD(SC)	1297213	3300000	0	1713330	17081	152933	58778	0	0	0	1942122	2655091
R.DHIANSAR(SC)	1153437	3400000	0	1746281	33767	264865	291543	70378	0	0	2406834	2146603
ANANTAPUR(ORP)	219003	1900000	0	949236	31136	203012	0	0	0	0	1183384	935619
ARJIA(ORP)	-20674	1900000	0	1363860	29830	189385	0	29900	0	0	1612975	266351
B.SAUNKHRI(ORP)	-181609	1900000	0	1458177	39577	179587	0	25200	0	0	1702541	15850
BANGALORE(ORP)	-87498	1900000	0	1463329	26813	179947	29900	0	0	0	1699989	112513
HISAR(ORP)	221039	1900000	0	1629772	29256	198467	0	0	0	0	1857495	263544
INDORE(ORP)	15555	1900000	0	1119786	33832	179491	0	0	0	0	1333109	582446
RANCHI(ORP)	-145834	1900000	0	1136160	7117	163167	0	0	0	0	1306444	447722
SOLAPUR(ORP)	154980	2200000	0	1032000	35000	176000	0	32000	0	0	1275000	1079980
JHANSI(vl.centre	0	130000	0	0	1900	45000	0	0	0	0	46900	83100

Acronyms

AAU ..... Assam Agricultural University
ACIAR ..... Australian Council for International Agricultural Research
AESR ..... Agroecological Subregion
AICRPAM ..... All India Coordinated Research Project for Agrometeorology
AICRPDA ..... All India Coordinated Research Project for Dryland Agriculture
ANGRAU ..... Acharya NG Ranga Agricultural University
AP Cess ..... Agricultural Price Cess
AWC ..... Available Water Capacity
B:C ratio ..... Benefit: cost ratio
BHU ..... Banaras Hindu University
^{0}C ..... Degrees Celsius
CAZRI ..... Central Arid Zone Research Institute
CC ..... Cubic centimeter
CCSHAU ..... Chaudhury Charan Singh Haryana Agricultural University
CEC ..... Cation Exchange Capacity
cm ..... Centimeter
CRIDA ..... Central Research Institute for Dryland Agriculture
CSIR ..... Council for Industrial Research
CSWCR& TI .... Central Soil and Water Conservation Research and Training Institute
CT ..... Conventional tillage
cv ..... Cultivar
DAS ..... Days after sowing
DFID ..... Department for International Development
DMR ..... Directorate of Maize Research
DOR ..... Directorate of Oilseeds Research
DRR ..... Directorate of Rice Research
EC ..... Electrical conductivity
EFYM ..... Enriched farmyard manure
Fig ..... Figure
FLD ..... Frontline demonstration
FYM ..... Farmyard manure
g ..... Gram
GEY ..... Grain equivalent yield
GLM ..... Green leaf manure
GRD ..... General recommended dose
ha ..... Hectare
HW ..... Hand weeding
ICAR ..... Indian Council of Agricultural Research
ICRISAT ..... International Crops Research Institute for SemiArid Tropics
IGAU ..... Indira Gandhi Agricultural University
IGFRI ..... Indian Grassland and Fodder Research Institute
INM ..... Integrated nutrient management
IVT ..... Initial varietal trial
IWMI ..... International Water Management Institute
JAU ..... Junagadh Agricultural University
JNKVV ..... Jawaharlal Nehru Krishi Vishwa Vidyalay
K ..... Potassium
kg ..... Kilo gram
LER ..... Land equivalent ratio
LGP ..... Length of Growing Period
lit ..... Litre
LT ..... Low tillage
MAU ..... Marathwada Agricultural University
mhos ..... Milli mhos
MLT ..... Multi locational trial
mm ..... Millimeter
MoR ..... Ministry of Rural Development
MoWR ..... Ministry of Water Resources
MPKV ..... Mahatma Phule Krishi Vidyapeeth
MPUA&T ..... Maha Rana Pratap University of Agriculture& Technology
MSL ..... Mean Sea Level
N ..... Nitrogen
NDUAT ..... Narendra Dev University of Agriculture & Technology
OC ..... Organic carbon
OFR ..... On-farm residue
ORP ..... Operational Research Project
OST ..... Off season tillage
OUAT ..... Orissa University of Agriculture &Technology
P ..... Phosphorous
PAU ..... Punjab Agricultural University
PC ..... Project Coordinator
PDKV ..... Dr.Panjabrao Krishi Vidyapeeth
PPIC ..... Phosphate and Potash India
QRT ..... Quinquennial Review Team
RDF ..... Recommended dose of fertilizer
RF ..... Rainfall
Rs ..... Rupees
SAU ..... State Agricultural University
SKDAU ..... Sardar Krushinagar Dantiwda Agricultural University
SKNagar ..... Sardarkrushi Nagar
SKUAS&T ..... Sher-e-Kashmir University of Agricultural Sciences & Technology
SMW ..... Standard Meteorological Week
SYI ..... Sustainable Yield Index
t ..... Tonnes
TNAU ..... TamilNadu Agricultural University
TSH ..... Tri-specific hybrid
UAS_B ..... University of Agricultural Sciences, Bangalore
UAS_D ..... University Agricultural Sciences, Dharawad

All India Coordinated Research Project for Dryland Agriculture

Central Research Institute for Dryland Agriculture

Santoshnagar, Hyderabad - 500 059

Web : http://www.crida.ernet.in